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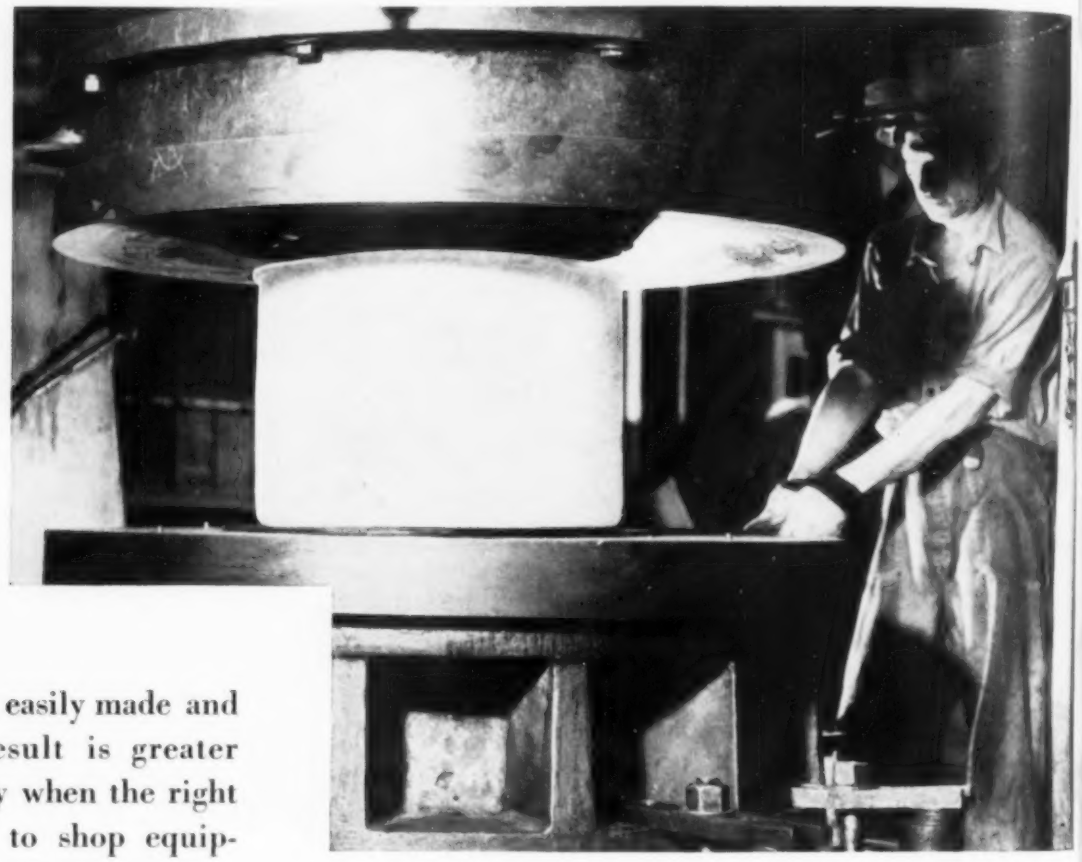

By R. H. McCarroll
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Cast Steel Parts *for the* Ford Tractor

A DISCUSSION OF THE ABOVE TITLE is timely, not only because of the program for general foundry expansion at the Rouge plant in Dearborn, Mich., but also because the newly designed tractor and several accompanying agricultural implements contain an unusually high proportion of steel and other castings. The total weight of our tractor is 2100 lb., and castings account for more than 50% of the total. The total weight of castings is 1155 lb., of which 553 lb. are gray iron, 173 lb. are malleable iron, 48 lb. miscellaneous non-ferrous castings, and 381 lb. steel castings.

Steel castings were introduced into the Ford tractor much more easily and to even better advantage than into Ford cars and trucks. The design of the tractor was started with the idea of making the best possible use of new materials, and of processes developed in recent years for the production of steel castings. From the beginning the metallurgists and foundrymen cooperated with the engineers.

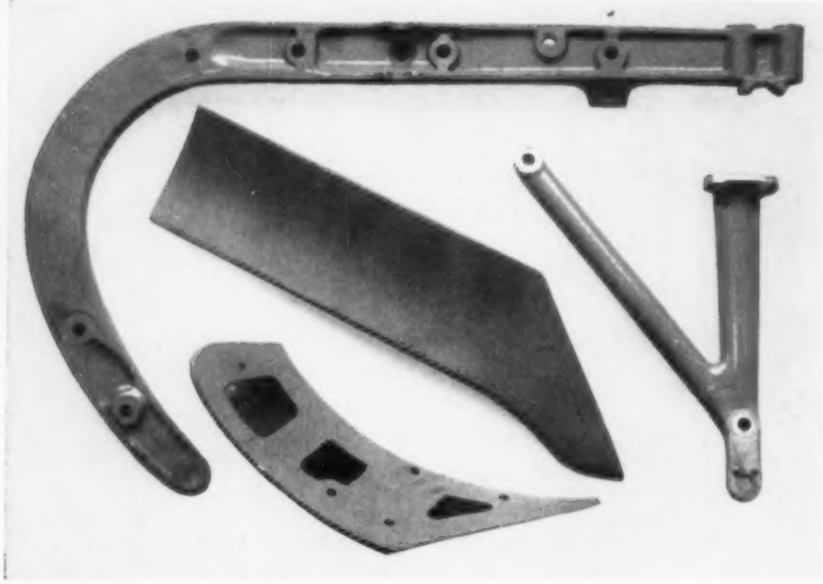
Probably many are familiar with the revolutionary principle on which the new tractor is built. By means of an unique linkage system and an in-built hydraulic control mechanism, the tractor carries as well as pulls the implement, and thereby eliminates the necessity for weight in both the tractor and the implement. One of the primary requirements, in fact, was low weight, and the extensive use of castings helped in achieving it, since the material could in that way be distributed to greatest advantage. To many it will be a surprise to learn that a tractor plus a two-bottom 14-in. plow weighs only 2410 lb. as against about 4000 lb. for conventional units.

Changes in the Foundry — The main purpose of the revisions in the steel foundry is to pour steel castings continuously instead of intermittently. This was achieved by utilizing electric holding furnaces for the metal, and conveyor reels for bringing the molds direct to pouring spouts. This system not only saves time but also produces more uniform castings, because the metal for each casting is delivered at uniform temperature and is of uniform composition. Each steel casting unit is operated in a synchronized system, but fully automatic pouring is not feasible except for parts of uniform weight, such as crankshafts.

Front axles, radius rods, steering sectors and wheel flanges are representative of parts made in one unit of 80 tons capacity in 16 hr. In addition to the main melting furnace and the holding furnace, there is a 2-ton cold melt furnace for special analyses. This, of course, lends flexibility to the system.

For the production of small tractor and car parts, there is a similar but smaller system. This unit consists of a reel which carries sand molds, made by vibrator molding machines, to a holding furnace where the molds are poured semi-automatically as in the larger installation. A melting furnace supplies metal at the rate of 40 tons in 16 hr. and the metal is transferred directly through a trough to the holding furnace. Clutch pedals, shifter forks, hydraulic lift arms and a dozen parts of similar size are made here.

Castings from either unit are shaken out and gates and risers are removed. The heat



Typical Castings for 14-In. Plow

treating furnaces are near the shake-out so that heat loss is minimized. Here castings are either heated, quenched and drawn, or they are annealed according to requirements. Many parts are quenched in fixtures to minimize changes in shape — and even correct some casting warpage. Emerging from the heat treat, they are cleaned and inspected. Some are also tested here.

The equipment described above is capable of producing enough sand castings for 400 tractors a day.

Sharing interest with these units is the equipment for centrifugal casting of gear blanks in permanent molds. This was described in some detail in various journals after its successful development for passenger car gears. It has now been adapted to the production of three tractor transmission gears and tractor differential gears.

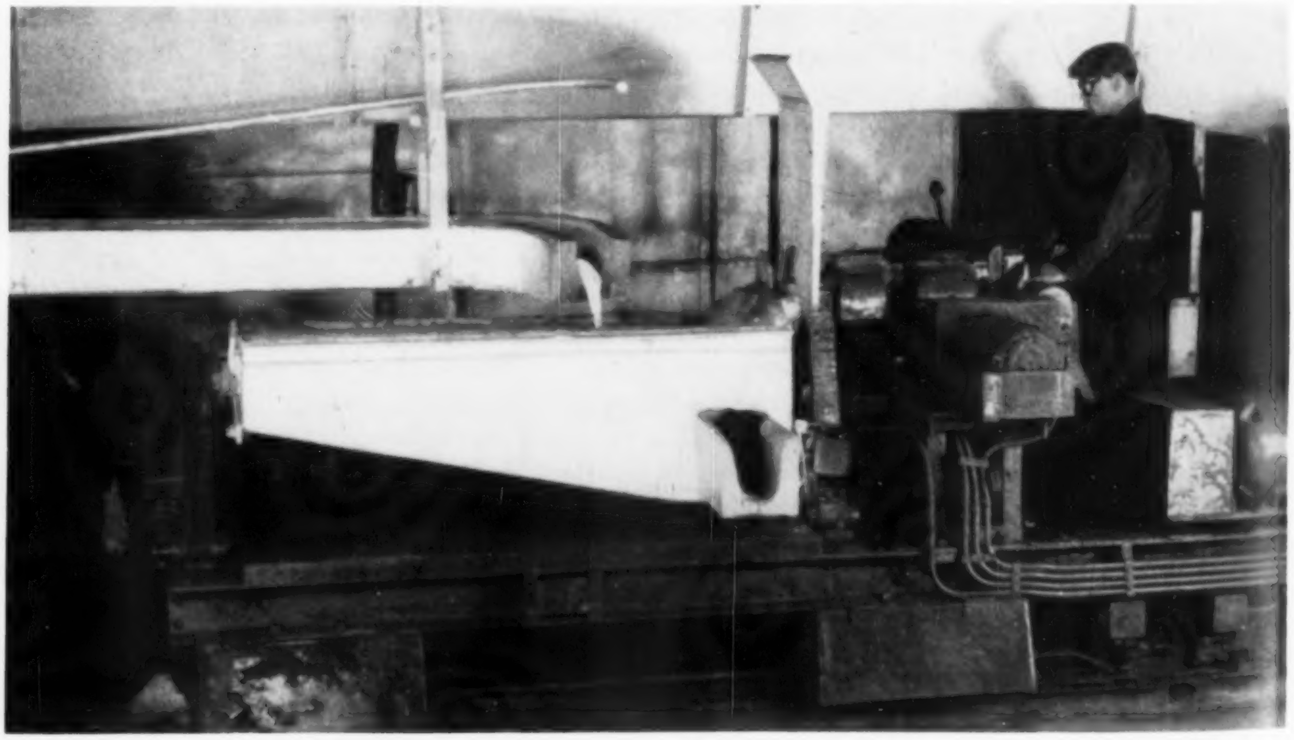
There are now four rotary casting tables, each carrying 18 centrifugal dies. To supply them a 15-ton electric furnace feeds metal into a 10-ton holding furnace. There also is a 2-ton cold melt furnace for special steels needed in smaller quantities, and a second one of the same size will soon be installed. Conveyor lines, annealing furnaces and other equipment complete the centrifugal unit.

As shown in sketches and description at the end of this article, the top section of each centrifugal die is removable. A conveyor circulates spare dies, supplying the rotary casting tables. This conveyor serves both for storage and for cooling.

Cast blanks removed from the dies are placed on a floor level conveyor leading to the annealing furnaces. A feature of this conveyor is that it operates at slow speed, and a sample from each group of castings is analyzed spectroscopically while the remainder is in transit (see the article in METAL PROGRESS for last July).

Another recent development is the automatic crankshaft casting. Both passenger car and tractor crankshafts will be poured with this equipment, which consists principally of two continuous forehearth cupolas, an electric

Automatic Pouring Car for Transfer of Molten Steel From Holding Furnace to Crankshaft Molds



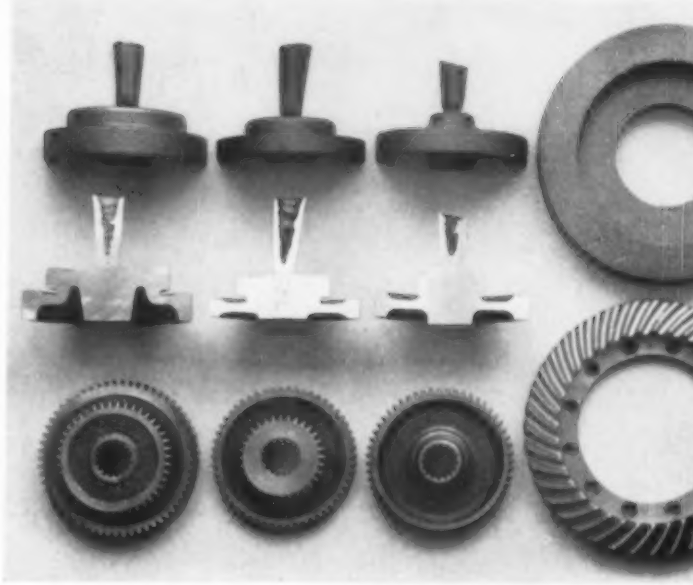
furnace, a holding furnace and a pouring car such as is shown in the view on page 522. Formerly the steel was melted in electric furnaces and poured into the crankshaft molds from ladles. With the new system, the steel will be melted in the forehearth cupolas, which will continuously supply molten steel of uniform composition. These melting units may be described as "stack charged air furnaces". They are fired with pulverized coal at the discharge end of the hearth. The combustion gases go up the stack and preheat the incoming charge. About 300 lb. of coal per ton of metal is required. Metal is poured from the cupolas at relatively low temperatures (about 2750° F.) to save refractories, and then brought up to pouring temperature in a 15-ton electric furnace. From there it is transferred to a holding furnace which also is fired by pulverized coal. The metal then flows into a pouring car and is poured automatically into crankshaft molds.

A possible method of pouring small steel castings can be illustrated by showing how it is now used for producing the pasenger car transmission housing in gray iron. Molten iron runs from one of two 96-in. cupolas into a 15-ton holding furnace. It flows from this furnace into one of 12 refractory-lined bowls located around the outside of a revolving table. Each bowl is automatically filled, and revolves around an axis geared to the reel carrying the molds until it meets the mold coming into position on the conveyor line. A cam then causes the bowl to tilt at a given speed and so pours the metal into the mold. The bowl continues around to take another charge while the conveyor brings new molds into position. Approximately 125 tons of iron can be poured in an 8-hr. shift.

Types of Steel in Use — To meet the physical properties of so many different castings, several types of steel are, of course, necessary, as well as a variety of heat treatments.

Type No. 1 is used for sand cast parts that are to be welded, or that are to be surface hardened by cyaniding. Its analysis and properties after being normalized to 163 Brinell hardness (hardnesses between 137 and 197 are used) are as follows:

Carbon	0.25 to 0.35%	Elastic limit	53,800 psi.
Copper	1.50 to 2.00	Tensile strength	71,100
Silicon	0.60 to 0.80	Elongation in 2 in.	18.5%
Manganese	0.40 to 0.60	Reduction of area	33
Phosphorus	0.05 max.		
Sulphur	0.08 max.		

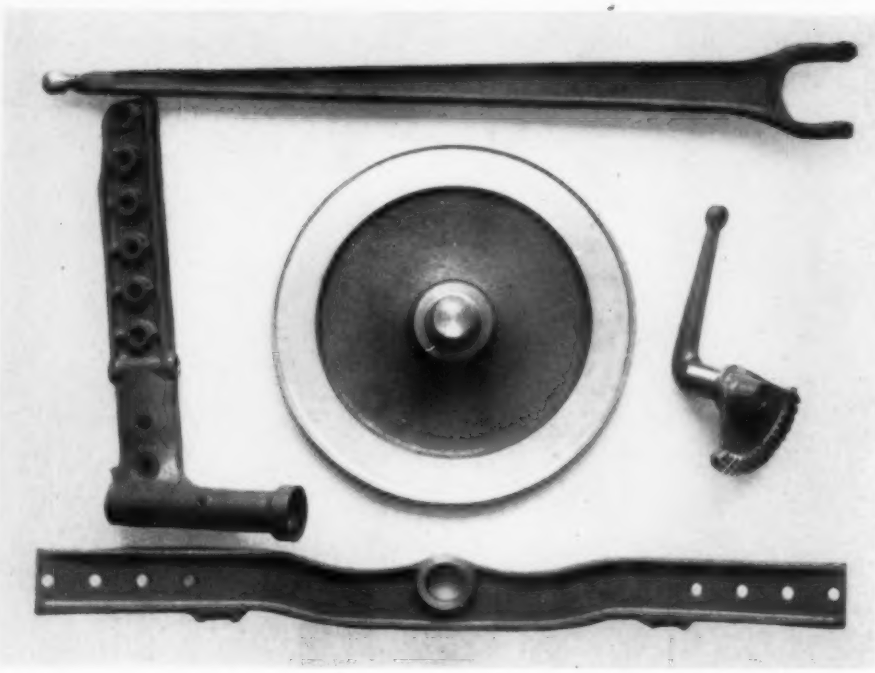


Cast Gear Blanks (Some Sectioned) and Finished Gears

It will be noted that carbon and manganese are low so that areas adjacent to welds do not harden, or so that surface hardened parts retain a soft core. We do not have an example of a welded part of this type of steel on the tractor, but we have several on the Ford car; one is the steering wheel hub used on one model for over a year, and in use now on two 1940 models. There are several of the surface hardened parts used on the tractor — for example, hydraulic lift rods and ram arms.

Type No. 2 is an S.A.E. 4620 steel only very slightly modified but containing 0.50 to 1.50% copper, as requirements dictate. It is used for the same purpose that the rolled S.A.E. 4620 is used — namely, for parts that require a good wearing surface and a tough core. An example is the tractor differential gear. Heat treatment is to normalize and then carburize after machining. Quench direct or reheat and oil quench. In any event the hardened gear is Rockwell C-58 to C-62 after drawing.

Type No. 3 is a modification of S.A.E. 5135 (or rather X4135, for it contains 0.10 to 0.20% molybdenum). The principal change is the addition of 0.50 to 1.50% copper. Passenger car transmission counter shaft gear and differential ring gear blanks are cast of this analysis. Type No. 3B is used for truck and tractor transmission gears. This part is given a light carbon case, and the carbon is run slightly higher than No. 3, being 0.38 to 0.45, because the larger sections and greater loads make a harder core advisable. Centrifugal gear blanks such as the ones shown at the head of this column are normalized to Brinell 170 to 196, cut, then hardened as specified on the blueprint. Representative properties of normalized castings of Type No. 3, and some after oil quenching from 1500° F. and



Large Tractor Castings of Steel

drawing at various temperatures, are given in the table at the right.

The bulk of the tractor castings is made of Type No. 4, a copper steel containing 0.35 to 0.45% carbon, 0.50 to 1.50% copper, 0.20 to 0.40% silicon, 0.70 to 0.90% manganese, 0.05% max. phosphorus and 0.05% max. sulphur. Most of the parts are annealed to Brinell of 163 to 207 and water quenched and drawn to give the greatest possible toughness; they are used in various hardness ranges as shown in the table below. Typical examples are radius rods, front axles, steering sectors and rear axle flanges. This analysis No. 4 is also used extensively on implements; a good example is the plow beam, which is used at a hardness of about 340. Modulus of elasticity of the quenched and drawn castings is 28,400,000 psi.

Properties of Copper Steel Castings, Made in Sand and Heat Treated

Property	Normalized	Annealed, Water Quenched From 1470° F. and Drawn at			
		1125° F.	1000° F.	850° F.	750° F.
Elastic limit, psi.	65,120	108,150	129,500	152,900	171,700
Tensile strength, psi.	90,750	128,620	139,200	157,500	173,600
Elongation in 2 in., %	15.2	10.0	8.0	5.5	5.0
Reduction of area, %	26.0	22.0	19.7	13.6	10.7
Brinell hardness	192	277	302	341	364

Type No. 6 is used for balls and races. It is naturally of high carbon (0.90 to 1.10) and chromium (1.10 to 1.30%). In general the treatment is to normalize, grind to shape, quench and draw to Rockwell C-62 to C-65.

Analysis No. 7 is used where high tensile strength is required, but where much ductility is not needed, such as for the truck rear axle housing and the furrow wheel on the plow unit. Composition and properties of Type No. 7 castings in the normalized condition are:

Carbon	1.35 to 1.55	Elastic limit	84,000 psi.
Silicon	0.90 to 1.10	Ultimate	103,000 psi.
Manganese	0.40 to 0.60	Elongation	9.0%
Chromium	0.08% max.	Brinell	207
Phosphorus	0.10% max.	Modulus	24,400,000 psi.
Sulphur	0.08% max.		

Hardness of 170 to 228 Brinell may be had

Properties of Centrifugal Gear Blanks After Heat Treatment

Property and Manner Cast	Normalized	Normalized, Oil Quenched From 1500° F. and Drawn at				
		950° F.	850° F.	800° F.	425° F.	355° F.
Elastic limit; *centrifugal*	*47,000 psi.*	*136,000*	....	*166,000*	....	*212,000*
sand cast	44,000 psi.	135,000	142,000	150,000	192,000	207,000
Tensile strength; *centrifugal*	*85,000 psi.*	*140,000*	....	*180,000*	....	*218,000*
sand cast	87,000 psi.	144,000	148,000	166,000	199,000	221,000
Elongation in 2 in.;						
centrifugal	*21.0%*	*7.0*	....	*3.0*	....	*0.75*
sand cast	18.0%	6.0	5.0	2.0	1.5	0.5
Reduction; *centrifugal*	*35.0%*	*14.0*	....	*5.3*	....	*3.0*
sand cast	28.0%	13.3	14.6	5.3	3.6	3.0
Brinell hardness; *centrifugal*	*160*	*302*	....	*364*	....	*477*
sand cast	160	302	321	364	430	477

by a simple anneal at 1650° F. for 30 min., followed by slow cooling to about 1100° F.

As the crankshaft steel and the job of casting it have been discussed extensively in the technical journals, most readers are quite familiar with its characteristics. The tractor crankshaft fits right into a system that has produced more than 5,000,000 car and truck shafts in the past six years. A very similar steel is used chiefly for pistons. This job is also not new and over 24,000,000 sand cast pistons have been produced in the past four years. To complete the record the following figures represent analysis and properties of the castings after a double heating: Heat 20 min. at 1650° F.,

air cool to a maximum of 1200° F., reheat to 1400° F. and hold 1 hr., furnace cool to 1000° F.

	Crankshaft	Piston
Analysis		
Carbon	1.35 to 1.60	1.40 to 1.60
Copper	1.50 to 2.00	2.00 to 2.50
Silicon	0.85 to 1.10	0.90 to 1.10
Manganese	0.70 to 0.90	0.80 to 1.00
Chromium	0.40 to 0.50	0.15 to 0.20
Phosphorus	0.10 max.	0.10 max.
Sulphur	0.08 max.	0.08 max.
Physical properties		
Elastic limit	95,080 psi.	85,000 psi.
Tensile strength	120,250 psi.	104,710 psi.
Elongation in 2 in.	6.5%	7.5%
Brinell hardness	255	229
Modulus	27,000,000 psi.	....

Valves and valve seat inserts are both cast of high alloy steel. Valve inserts (15% tungsten, 3% chromium, 1.75% copper, and 1.30% carbon) are heated 30 min. to 1450° F., and cooled in 3 hr. to 1000° F. Hardness is Rockwell C-38 to C-46. Valves are of 15% nickel, 16% chromium, 3% silicon and 1.10% carbon.

Upon studying the physical properties it can be seen that steel castings, besides having advantages already mentioned, can be counted on for properties comparable to those of forged steel.

Small Tractor Castings of Steel

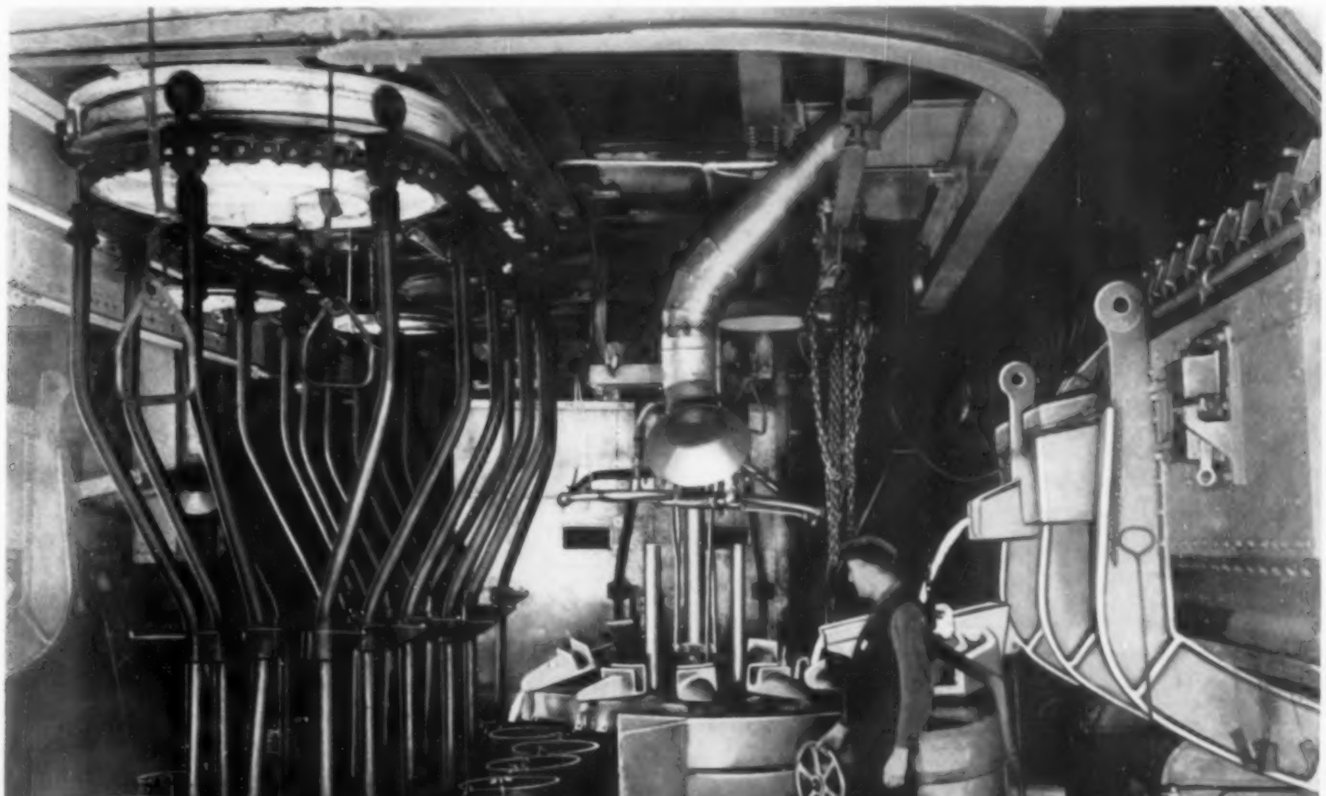
Depending on the particular part requirement, some of these types are used with only an annealing treatment, while others are heat treated to various hardnesses. It can be seen that the properties of the heat treated bars of Types No. 3 and 4 indicate clearly that these steels would be entirely satisfactory for highly stressed parts such as gears, front axles and plow beams.

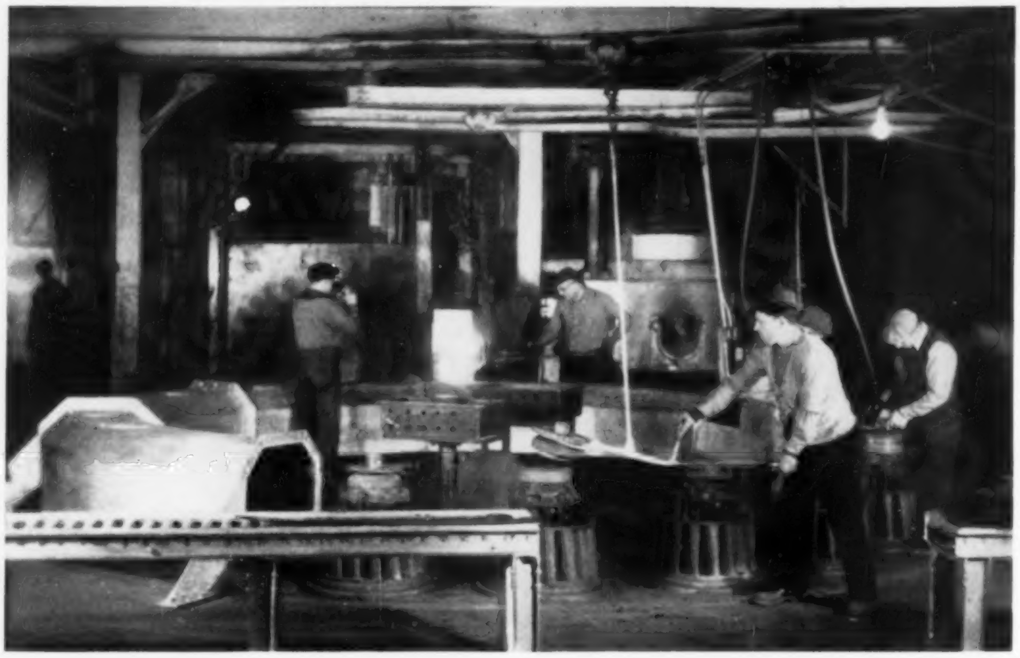
One interesting recent development requiring special physical properties is the cast plowshare. This has to be very hard on the point but of a modified hardness on other portions of share. We have been able to get very good results using No. 3 steel with a special heat treatment.

Methods of Manufacture—Having described equipment for making, the analysis and the physical properties of steel castings, we want to consider briefly the methods of manufacture.

These are divided into three principal classes — green sand castings, dry sand castings, and centrifugal permanent mold castings.

Small Parts, Molded on Vibrators, Are Carried to an Electrically Heated Holding Furnace and Cast at Uniform Temperature. Automatic pouring is feasible, by means of transfer bowls tilted by cam at the proper spot, although now done only for gray iron castings



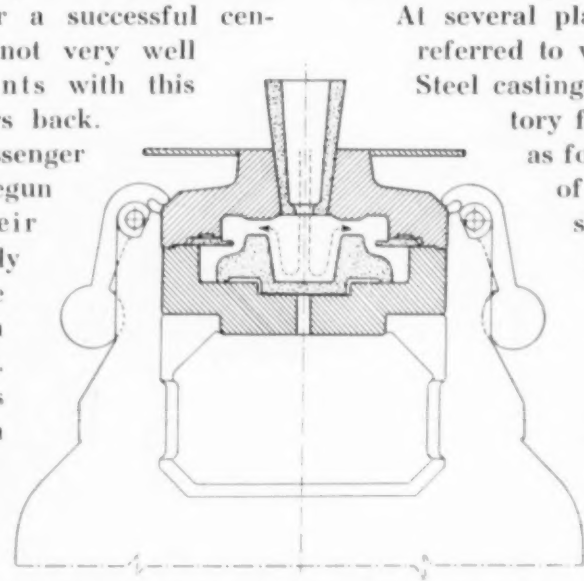


Unit for the Centrifugal Casting of Gear Blanks of Modified S.A.E. 4620 and X4135. In background is a 15-ton electric melting furnace and a 10-ton holding furnace; ladleman pours one casting while pyrometer man checks the temperature; turntable moving counter clockwise carries molds under hood while cooling; man in right foreground transfers mold top and casting to conveyors, while other workmen behind him place the cores and reassemble mold

Green sand is the most widely used material for molds. Our practice is to make as many castings as possible in one mold and in some instances the sections of molds are stacked, thus making several layers of castings at one pour. Quality in sand castings depends of course on a number of conditions; among them are correct analysis of metal, fluidity, correct degree of deoxidation, proper gating and venting of molds, correct condition of sand as to permeability, bond strength and percentage of moisture. We use a permeability of about 120 (American Foundrymen's Association standard) for large castings and about 100 for small castings, the bond strength being 10 to 12 on both of these, and the moisture about 3%.

Dry sand molds are used for very heavy castings that require a great degree of accuracy in size and shape. The cast crankshaft is the typical example of a heavy casting so made.

The requirements for a successful centrifugal die casting are not very well known. Our experiments with this method date several years back. Partial production of passenger car and truck gears was begun two years ago, and their decided success led naturally to adaptation of the same method to the production of tractor gear blanks. Gear blanks, requiring as they do particularly high quality metal in the portions where the teeth are cut, are well suited to the method. The centrifugal force produces castings free of imperfections, and the metal cools so rapidly against the metal mold that the dendritic formation is retarded or entirely absent. Speed of spinning, incidentally, is not high, ranging from 250 to 400 r.p.m., depending on the outside diameter of the gear.



Sketch of Centrifugal Mold for Casting Tractor Transmission Gear, Low and High

The molds are designed simply, with enough bulk to dissipate the heat. To overcome the "cutting action" of incoming metal, small cores are used on which the metal strikes, and a core is nearly always required for some undercut in the gear. By considering this when designing the mold, it usually is possible to use the same core both to protect the mold and to produce the correct undercut in the gear.

We have been able to get very good life from our molds. We have several satisfactory analyses, but have not yet definitely set on any one to the exclusion of the others. The major requirement is for a low carbon material, under 0.25%. Varying amounts of molybdenum and chromium may be used with this, both in combination and separately.

At several places in this paper we have referred to various parts of implements. Steel castings have proven very satisfactory for these implements as well as for the tractor itself. Evidence of our conviction of this is shown by the fact the plow unit weighs 310 lb., and steel castings account for 200 lb. of this, including such parts as the beam and the share. Because of the greater flexibility in design permitted by the casting method, weight is saved and of course these parts can be made at lower cost than is possible by forging.

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Some of the Chemistry of Electric Steel Melting

Late in March Battelle Memorial Institute was host to about 175 melters of electric steel who, in three days, heard a series of lectures concerning the science and art of their business. R. L. Baldwin of National Carbon Co. deserves credit for laying the groundwork of this conference; it was sponsored by the Steel Founders Society and the Electric Metal Makers Guild.

The lectures covered many phases of electric steel melting including electric furnace equipment and its maintenance, power control, fluidity and temperature measurement, metal handling, and the fundamentals of the chemistry of both acid and basic practice. They fell into two broad classes: Those having to do with the actual operations, and those having to do with the fundamental chemistry of steel making. In the limited space available, only the latter can be outlined.

"Fundamental Physical Chemistry of Steel Making" was the topic chosen by Charles H. Herty, research engineer for Bethlehem Steel Co., and known internationally for his work in this field. He said that much had been written about the dynamics and thermal effects of reactions assumed to be taking place at 2700 to 3100° F., but that these equilibria were only one of four general actions that must be recognized: 1, Solubility, 2, Reactions and equilibrium, 3, Diffusion and 4, Flotation.

Each one of these fundamental actions was individually discussed and will now be briefly abstracted.

1. *Solubility* — One of the first things that happens in steel melting is that FeO gets into the metal. (It later is useful in removing certain undesirable elements.) The rate of solubility depends on the temperature; increasing temperatures accelerate the rate and greater quantities can be dissolved at increased temperatures. Thus, at the melting point of steel only about 1% FeO can be dissolved in iron but with higher temperature this is greatly increased.

Iron oxide is only one of the constituents that may find itself either in the molten metal or the slag. One problem in physical chemistry is to determine how this partition changes with circumstances, and it has been found that for each temperature there is a certain "distribution ratio". For example: The amount of FeO dissolved in the steel is proportional to the amount present in the slag. This proportion remains constant at a given temperature — that is to say, given enough time to attain equilibrium, there is no further change in the relative amounts. Iron oxide leaving the metal bath for the slag is matched by an equal amount leaving the slag somewhere else and entering the metal. If the temperature should then rise, the equilibrium would be upset, and the oxide would go from metal to slag (or vice versa) until a new distribution ratio is established at a new constant temperature. This same principle applies to other elements that will dissolve in both steel and slag.

2. *Reactions and Equilibrium* — To illustrate the mechanism of chemical reactions Dr. Herty took the case of a steel bath containing 1% Mn to which FeO was added (by oreing or otherwise) so as to upset the equilibrium within the steel itself. The reaction to be expected would be: $Mn + FeO \rightarrow MnO + Fe + heat$.

Photo by Rittase

The End of the Heat

When equilibrium has been reached the reaction may be thought of as going in both directions simultaneously:

$$Mn + FeO \rightleftarrows MnO + Fe$$

If MnO were added in place of FeO the reaction would go in the reverse direction:

$$Mn + FeO \leftarrow MnO + Fe - heat$$

Since the oxidation of manganese gives off more heat (54,200 units) than the dissociation of an equivalent amount of iron oxide absorbs (33,950 units), the reaction generates heat when it moves from left to right. Such an exothermic reaction may reverse if the temperature rises sufficiently (or, more properly, come to equilibrium with more FeO present), which corresponds to the known fact that the deoxidizing power of manganese diminishes with increasing temperature.

For silicon the typical reaction is:

$$Si + 2FeO \rightleftarrows SiO_2 + 2Fe + heat$$

The heat balance from oxidation, reduction and solution results in a larger amount evolved than in the manganese reaction. If the metal increases in temperature, this reaction "reverses" in the sense noted above. Thus, the amount of silicon reduced from silica in slag particles or from the lining in an acid furnace increases with increasing temperature.

As noted, if the reaction *absorbs* heat, it tends to increase in activity with increased temperature. Phosphorus control is based on this fact. The reactions are complicated, and actual data on heat evolution are missing, but there usually is an increase in phosphorus in the metal with increased metal temperature, other things being equal.

The reaction between carbon and FeO is:

$$C + FeO \rightarrow CO\uparrow + Fe$$

In this reaction the CO is only slightly soluble in the metal, the greater quantity going off as a gas. This reaction continues in the one direction because one of the products is rapidly removed from the steel. The slight solubility of CO is the only reason it is not possible to make absolutely carbon-free iron easily. This type of reaction tends to go to completion, rapidly at first, but slowing down as equilibrium is approached.

From this brief discussion we see that there are two typical classes of reactions involving characteristic types of products:

1. Reaction products that may reverse, interchange, and reach apparent equilibrium.

2. Reaction products, one of which leaves the furnace and therefore the reaction trends definitely in one direction only. Of course, removal of a slag will prevent reversal of reactions between metal bath and slag cover.

The *speed* of reaction is proportional to the concentration existing in the reacting media. In the case of manganese and silicon the rate of reversal depends on the analysis of both metal and slag. The distribution ratio for manganese may be denoted by K_{Mn}, and this is calculated from the equation

$$K_{Mn} = \frac{(MnO)\cdot[Fe]}{(FeO)\cdot[Mn]}$$

where the parentheses indicate that the concentrations to be used are those in the slag, and the brackets the concentrations in the metal.

3. *Diffusion* — To bring about good reaction between slag and metal, they should be in intimate contact. Transfer or reaction between the slag and metal layers takes place at the interface only. Solution or transfer requires a concentration gradient, and the rate of solution is proportional to the difference of concentration between the two media.

Diffusion rate also depends upon the viscosity of the media. Slag is far more viscous than the steel. The steel is so fluid that some elements go through it very fast. For example: When silicon is added to the metal bath, a goodly part of any reaction it induces is complete in about 7 min. It follows that for maximum rate of diffusion between slag and metal, the slag should be as fluid as possible. Stirring will help to break up the stratification that takes place at the slag-metal interface, and speed up the reactions.

4. *Flotation* — If dirt is thrown into water, a settling rate, varying with particle size, can be observed. Large particles separate rapidly and the more minute particles settle at a very slow rate. If hot water were used, the settling of even fine particles would take place more rapidly. Thus, the speed of settling depends *(a)* on the size of the particles and *(b)* on the viscosity of the liquid.

In steel the settling is *up* rather than down, due to the relative specific gravities of the materials involved. Increased temperature will cause particles to float out faster; likewise increased size of particles will cause them to rise more rapidly. Further, increased temperature makes slag particles more fluid, increasing their tendency to coalesce and come up at a more rapid rate.

To produce clean steel it is necessary that the fine particles be removed from the metal.

A cool heat will probably be dirty because the finely dispersed particles existing were not able to coalesce and float out.

The somewhat general remarks by CHARLES HERTY were then supplemented by C. E. SIMS, research metallurgist at Battelle Memorial Institute, who pointed out that conditions were greatly complicated by the number of reactive substances present in an electric furnace heat. For instance, the "basic" oxides present in the steel making process are CaO, MgO, FeO, MnO, Al_2O_3, and the "acid" oxides are SiO_2, Fe_2O_3, Mn_2O_3, Al_2O_3 and P_2O_5.

Pure SiO_2 and CaO have very high melting points. To utilize them as slag making materials, they should be sufficiently fluid to act as a suitable carrying agent. Fluxing can be obtained in two ways:

1. By chemical combination — a base plus an acid results in a low melting point slag. Thus:

$$CaO + SiO_2 \rightarrow CaO \cdot SiO_2$$

Melting points of these three substances are 4660°, 3115°, and 2800° F. respectively.

2. By causing one substance to become soluble in another. In acid practice, we may have FeO dissolved in SiO_2 in varying proportions.

An oxidizing slag has been variously defined; it may be thought of as one having a tendency to give up oxygen to the steel. Oxygen in slag may be closely held in a stable compound, or rather loosely held in a compound that can readily migrate — so loosely held that it may act as free oxygen in solution.

For example, if the FeO is combined with SiO_2 in an acid slag, there can be but little reaction. However, by adding CaO the following reaction takes place:

$$FeO \cdot SiO_2 + CaO \rightarrow CaO \cdot SiO_2 + FeO$$

whereupon the FeO is available for solution or reaction in the metal. In basic practice if the FeO and the slag are combined as $CaO \cdot Fe_2O_3$, the slag is very fluid and neutral, but if SiO_2 is added the oxidizing power will be increased because the chemical combination is broken up and the FeO is made available. Conversely in acid slag practice, a slag low in FeO and high in SiO_2 will take FeO from the steel.

In basic slag practice, a white slag deficient in FeO will rapidly dissolve FeO from the metal, in amount depending on its ability to enter into chemical combination.

Acid Slag Practice

In acid slag practice the phosphorus and sulphur cannot be removed from the steel. The oreing period has three functions:

1. To oxidize carbon.
2. To oxidize manganese (not as readily oxidized as silicon).
3. To oxidize silicon (readily oxidized).

In these reactions the first to reach prominence is

$$C + FeO \rightarrow Fe + CO \uparrow$$

When the FeO is depleted, the reactions slow down because of the approach to equilibrium. This reaction probably never quite reaches equilibrium due to resistance to bubble formation. The initial small bubble has very high surface tension and a pressure has to be built up to get a bubble started. Once started the bubble enlarges rapidly.

Some reactions involved are exothermic:

$$Si + FeO \rightarrow Fe + SiO_2 + heat$$

This liberates heat and materially raises the temperature of the bath. As pointed out in Dr. HERTY's lecture, the entire course of the reaction may be changed in superheated baths. In other words, the silica will react with iron to form iron oxide, and some silicon will be reduced from the slag. At temperatures above 3100° F. carbon becomes a better deoxidizer than silicon.

These principles explain why, in a small electric furnace, when a high degree of superheat is necessary — as for pouring intricate or thin-walled castings — it is virtually impossible to prevent the reduction of some silicon. This silicon may be reduced under furnace conditions that are oxidizing, as far as carbon is concerned.

Basic Slag Practice

In basic practice, we have about the same reactions between carbon, manganese, silicon and oxygen as in acid practice. Basic practice is also designed to take advantage of the high "affinity" of phosphorus for oxygen at relatively low temperatures. Mr. SIMS, to illustrate this point, did not use the simple reaction between elemental phosphorus and iron oxide (FeO) but wrote it thus:

$$2Fe_3P + 8FeO \rightarrow (FeO)_3P_2O_5 + 11Fe$$

This reaction will reach equilibrium quickly with the oxidation of but little phosphorus in the absence of free lime. In the pres-

ence of lime, however, a stable phosphate is formed by this reaction

$$(FeO)_3P_2O_5 + 3CaO \rightarrow (CaO)_3P_2O_5 + 3FeO$$

which acts to prevent reversal of the other reaction. This dephosphorizing reaction requires a large amount of FeO and free lime in the slag to remove much phosphorus. Dephosphorizing slags are usually removed from the furnace to prevent reversion of phosphorus to the metal.

Sulphur is removed from the bath by the following reaction

$$CaO + FeS \rightarrow CaS + FeO$$

and its transfer from bath to slag depends on the ratio of CaO to FeO in the slag. Since there is little CaO and much FeO in an acid slag, it absorbs little sulphur. The conditions are reversed in a basic slag. The calcium sulphide formed is very insoluble in the steel but highly soluble in the basic slag, and the reaction reaches equilibrium very quickly. Carbon added to such a slag to form a carbide slag prevents a reversal of the desulphurizing reaction by disposing of the FeO. Two reactions are effective:

$$CaO + FeS + C \rightarrow CaS + Fe + CO \uparrow$$

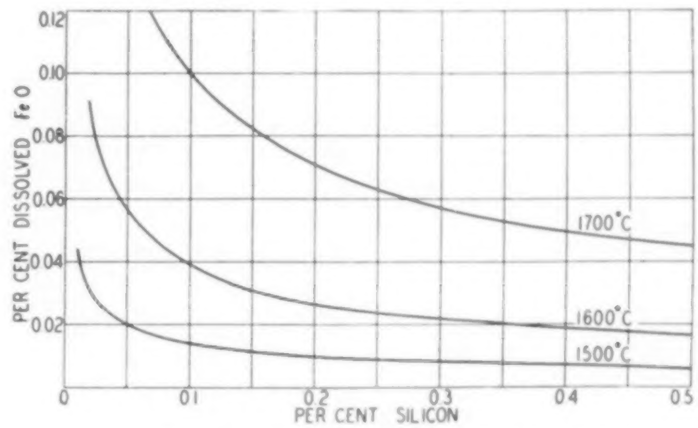
$$CaO + 3C \rightarrow CaC_2 + CO \uparrow$$

As remarked above, these equations travel as shown because one of the products is carried away permanently. Desulphurization of the metal can therefore be almost complete under a carbide slag.

Some curves showing the relation between time and reaction rates, especially at the approach to equilibrium (which, of course, does not usually mean 100% change from one substance to another), were shown by Mr. Sims, copied from John Chipman's paper "Application of Thermodynamics to the Deoxidation of Liquid Steel" in *Transactions* ⊕, April 1934. One showed the removal of carbon with time; it has a similar shape to the curve for removal of iron oxide (oxygen) by silicon at 1600° C. Both reactions start at a very high rate, and equilibrium is reached at a constantly lower speed. In both instances, however, the intended reactions do not go to completion, in the sense that *no* oxygen is left in the steel. Thus, in the reaction between FeO and Si at either 1500 or 1600° C. (2735 or 2910° F.) the FeO reaches a practical minimum with approximately 0.30% Si. Beyond this point additional Si does not do much to reduce the FeO below about 0.02% (see the curve for 1600° C.). If, however, the furnace were cooled, the FeO solubility would decrease and a point would be reached at which the metal would boil, the FeO reacting with the carbon in the molten steel.

The curves show that as the metal temperature is lowered, the efficiency of silicon as a deoxidizer increases. If the silicon is below 0.25%, there may be some reaction between FeO and carbon in the mold, forming CO gas. However, if ample silicon has been added and the finishing temperature of the metal is low enough, solid (non-gassy) steel should result. The residual FeO content may be reduced further by means of aluminum.

However, it may be found that the steel still effervesces. This must be due to nitrogen



Equilibrium Between FeO and Si in Molten Steel at Three Temperatures (Chipman)

or hydrogen or both. The source of the hydrogen may be from rust (a hydrated iron oxide), high humidity (moisture in the combustion air), or moist slag-forming materials.

The solubility of such gases as nitrogen and hydrogen in liquid steel increases with the temperature, and with the square root of the partial pressure of that gas in the atmosphere above the metal. To illustrate: If the partial pressure increased to four times, the gas absorption would double.

Hydrogen is eliminated during a boil from FeO, by the reaction

$$H_2 + FeO \rightarrow Fe + H_2O \uparrow$$

Nitrogen can also be swept out of the metal during a good boil. However, both hydrogen and nitrogen tend to remain in cooling metal even to supersaturation, and it is a problem to get them to form bubbles and eliminate themselves before entering the mold and causing porosity.

Commenting further on this problem of equilibrium, Mr. Sims said that if a bath has a certain amount of hydrogen and nitrogen in

solution and CO can be made to bubble up through the bath, the CO bubble itself will come to equilibrium with the bath and carry out its share of both hydrogen and nitrogen. If enough bubbles are formed, a fair amount of the two gases are removed in this way. Hydrogen can also be removed from metal in the oxidizing stage. However, if hydrogen is picked up while the metal is under a deoxidizing slag, it will not be removed. Slag forming materials, such as lime containing moisture, may be a source of hydrogen in the deoxidizing stage when making electric steel. The metal has its lowest hydrogen content immediately after the boil; from this, the value of a vigorous boil is evident when sound steel is to be cast.

Aluminum is the strongest of the common deoxidizers. When sufficient has been added it will reduce the FeO content of the steel to less than 0.001%, and minimize the reaction (the reverse of the one last written)

$$H_2O + Fe \rightarrow H_2 + FeO$$

in sand castings, therefore effectively preventing pinholes.

Sigma Phase (Finis)

By Martin Seyt

SIGMA PHASE (the iron-chromium compound that appears in many iron-chromium alloys containing nickel or manganese) seems to be achieving considerable nuisance value because of its current ubiquity in the metallurgical literature. More words on the matter are therefore written with some diffidence, although it seems worth while to point out that this harmless Greek letter, when attached to a phase — as was done a few years ago by Prof. ERIC JETTE at Columbia University — is now able to shed some light on the British blockade! In brief, it would appear that the British must be blockading themselves unilaterally and that the blockade is retroactive.

The basis for this supposition is this: There occurred in March of last year a coincidence in that METAL PROGRESS and *Archiv für das Eisenhüttenwesen* both carried diagrams which, for the first time, showed the effect of sigma phase on the iron-chromium-nickel diagram. (The principal difference in these publications was that one described the rather unusual construction as a "tent", the other as a "tunnel", but this may be explained on ideological grounds, the American author evidently being aware of an approaching camping trip during his vacation, and the Germans being fed with news about the underground fortifications on the West Wall.) At any rate the coincidence was noted in these United States and in Germany. A few months later *The Metallurgist*, of London, published one of its admirable reviews devoted to the sigma phase. The above mentioned data sheet in METAL PROGRESS was not mentioned, but it may be supposed that the March 1939 issue had not been in London long enough to be digested.

As the vigorous American language would put it, the payoff came a year later, for in the March, 1940, issue of *Metallurgia*, also of London, J. H. G. MONYPENNY reviews at length "The Brittle Phase in High Chromium Steels". Now, as all English and American speaking metallurgists know, Mr. MONYPENNY is an international expert on high chromium alloys and is the author of the first book ever to be written about Stainless Iron and Steel. He certainly should have had all the reliable data at hand yet it appears that not even he is aware that Mr. MARSH's diagrams in the American publication show more details of the "rather complex 'build-up' of these sections" than those of Messrs. SCHAFMEISTER and ERGANG in the German, for he does not even mention them.

I have been informed that the authors of these highly similar original discussions corresponded at once and it may be suspected that each was secretly gratified to be checked by the other. It may be concluded from these data, therefore, that mail from Germany reaches England as well as the United States, that mail from the United States reaches Germany, but that mail from the United States does not reach England, and did not even during the six months before the war. This is an aspect of alleged interference with Uncle Sam's mail that not even the more vociferous of our Congressmen have cited! In this same mail I am asking the editor of METAL PROGRESS to send Mr. MONYPENNY copies of the article, via Yankee Clipper, in the chance that when the mail is removed en route by British control officers it will be forwarded to the addressee, who may, with us, get a little smile out of the situation.

Critical Points

By the Editor

AFTER a trip through Bendix Products Corp.'s plant at South Bend was convinced that I should learn something about the working of carburetors. This little brass pot for mixing a little gas with a little air has grown into an aircraft accessory more complicated and more costly than a whole automobile engine, more precise than a watch, and more searchingly inspected and tested than a marine boiler. . . . . GEORGE STOLL, plant metallurgist, has a varied responsibility, and has put a technical manager and an operating superintendent in each of his four departments — foundry (iron, aluminum, zinc die cast), heat treating, plating, painting. . . . . Gray iron is melted in a 15-ton electric furnace using nothing but own scrap and purchased turnings. About a ton of metal is poured every 10 min. into a barrel-shaped fore hearth to serve the bull ladles, and an equivalent amount of cold charge put into the furnace. Three-minute carbon determinations are made in a Leco apparatus; silicon is judged by fracture of chill castings and checked every 2 hr. by chemical analysis. Temperature of each ladle-full is taken optically. The aim is to produce a close-grained iron, easily machined, by causing the graphite to appear in small flakes. . . . . Aluminum castings, such as the very complicated carburetor bodies, are cast in dry sand and core assemblies. Porosity is their bane; rejections always rise in the humid spring months, and are guarded against by an alert crew in the X-ray laboratory. . . . . FRED CRAVEN, heat treat foreman and secretary of the Notre Dame Chapter ⊕, was inspecting gas analyses from a new continuous carburizing furnace (no muffle, of Holcroft design). It works principally on universal shaft parts of S.A.E. 4620. 18 hr. in the furnace gives a penetration of 0.070 in. (± about 0.005 in., which is better than pot carburizing can do). One hour in a water jacketed exit lock brings the parts out clean of scale. Heat is from radiant tubes. The carburizing atmosphere is recirculated by external blower, and is constantly sweetened by additions of 1000-B.t.u. gas from the city mains. Excess spent gas goes to flush the entrance and exit locks or vestibules, or is vented to the outdoors. CO in the furnace atmosphere is about 10%, CH_4 about 22%. Hydrogen is high, CO_2 and O_2 are absent, moisture is undetermined but probably low. In this carburizing furnace the parts are supported on carefully designed trays. After emerging they are racked in a vertical fixture, heated in a pit type of furnace, and quenched vertically — thus minimizing distortion, or rather, controlling distortion in a uniform amount and direction. . . . . Electroplating department is unusually large, cleanly and odorless. Over 16,000 amperes are consumed in three chromium plating units whose principal job is to put a polished wear resistant surface on parts of aircraft landing gear — those plunger-like struts that operate like hydraulic pistons. In this plant (as well as others recently observed) zinc plating for rust resistance seems to be superseding cadmium. STOLL remelts scrap zinc from his die casting shop into anodes. Zinc plated parts are given a chromate dip; they are blotched by the chemical but they certainly do resist salt spray.

Advanced Foundry, Carburizing, and Plating Practice for Aircraft Parts

TO THE STUDEBAKER plant and found this sturdy independent again busy making durable motor cars. BILL HARRIS, the metallurgist, showed me many interesting things, including the grinding of top spring-leafs before heat treatment, not only to remove scale and decarburized skin, but also to reveal surface defects. Shot blasting after heat treatment appears to double their fatigue life. . . . . Many levers and brackets for the remote control gear shift are made of screw machine parts and steel stampings pressed together

and copper brazed in continuous furnaces, using partly burned city gas, freed of moisture, for the protective atmosphere. To avoid useless heating of the entire shaft assembly, the end attachments are pressed on, a stirrup of brass wire snapped in place along the joint, ten units racked up and the ends dipped into a Lavite bath for 2½ min. In this time not only is the heat necessary for brazing acquired but the shaft end is properly heated for a water quench to harden. HARRIS prefers such brazing to welding for its simplicity and for its easy visual inspection; copper drawn through the joint is evidence of reliability. . . . . Recent improvements in the spun-in babbitt on connecting rod main bearings start with rust proofing (Parkerizing) the rough forging at the outset. The bearing is bored and degreased. Electrolytic cleaning then produces a chemically clean surface on this bore, slightly etched and excellently adapted to fluxing and tinning — a preliminary step in babbitting. The crank end of the rod is dipped in molten tin the minimum time, to reduce the thickness of the tinned surface and the more-or-less brittle iron-tin alloying layer. The Parkerized surface prevents any tinning except at the bare steel bore. The rod is then placed in the spinning fixture (one of a dozen on a "merry-go-round") and a spoonful of babbitt poured into the center. Minimum time in the tin pot heats the connecting rod only mildly, so the babbitt chills quickly, thus promoting fine grain and preventing segregation. This train of operations is conveyorized (if there is such a word); three men are necessary at the babbitting wheel, one to transfer the rods from tin pot to fixture, one to ladle in the babbitt, one to unload the fixture. . . . .

Studebaker's Metallurgical Innovations

Studebaker cars use carburized S.A.E. 1020 camshafts to operate steel valves without intermediate white iron lifters. Seizure of steel rubbing on steel is prevented by a phosphate chemical treatment of the finished camshaft; therefore the steel lifter rubs not on steel but on an oxidized iron compound tightly bonded to the cam. The camshaft has a gear mid-length, and its manufacture involved double straightening and gear cutting after carburizing until a workman asked one day "What acid will dissolve copper and not dissolve steel?" The answer was, "Concentrated nitric." So now the shaft is copper plated; the cams carburized; the protective copper dissolved from the gear; the entire camshaft quenched from cyanide, drawn and straightened.

GLAD to find the Milwaukee Railroad's 90-mile-90-minute train from Chicago a complete sell-out; evidently the public appreciates and uses high speed transportation. . . . Attending the 40th convention of International Acetylene Association, whose history more than usually typifies the pace of American industry. First interested in the sale of calcium carbide and equipment for house lighting, 30 years ago the acetylene industry flourished as the source of the most reliable automobile light. 15 years ago oxy-acetylene welding and cutting became almost the sole interest of the Association's members, as judged by the discussions at the conventions; today the important news is about mechanical applications of the oxy-acetylene flame in the engineering industries unheard-of even ten years ago. Carbide and acetylene are seldom mentioned at the meetings, despite their rising importance as the base of many important synthetic chemicals. . . . . As befits maturity, the pace at the I.A.A. meeting is deliberate, with many opportunities for conversation and rallying-'round — even reminiscing, as was done by Wisconsin's Governor JULIUS HEIL, a man who prospered through the manufacture of barrels and tankage. He spoke of his first purchase of a Davis-Bournonville welding torch for $155, and he weighed it and marveled that brass could cost so much. Those were the good old days when new business, by his own admission, was not very attractive unless it would return about 400% profit. . . . .

No Occupational Diseases From Oxy-Acetylene Fabrications

Four physicians pooled their first-hand experience on industrial diseases, actually or reputedly due to gases and vapors incident to welding, and concluded that oxygen, acetylene and gases from the oxy-acetylene flame have such remote possibilities of toxic action that they may be correctly described as harmless. Of course, the use of intense temperatures involves certain well-recognized hazards and a body of safe practices has been established. Lead, zinc and cadmium fumes from the welding or cutting of alloys containing them or steels coated with them or painted with their compounds are the only real hazards in the way of occupational diseases, and these are easily controlled by elementary attention to ventilation, or by the use of air-supply masks.

"THERE'S ROMANCE in metallurgy," said HARRY IHRIG, "when some experiments on the carburizing of stainless steels can be responsible for a $150,000 order for tubes, and success for a new method for making high octane gasoline." In his experiments, IHRIG (who is director of laboratories for Globe Steel Tubes Co. in Milwaukee, and known to readers of METAL PROGRESS as the father of a process of siliconizing the surface of steel articles) merely confirmed his expectations that 18-8 would absorb lots of carbon into its austenitic structure; on the other hand, the ferritic chromium-iron alloys with 25 to 30%

27% Chromium-Iron Tubes for Oil Refining

chromium would not carburize, ferrite having negligible solubility for carbon even up to near the melting point. So when the oil refinery was trying everything — even to bronze linings — to find a tube that would not oxidize or carburize at 1300° F., and so poison the catalyst in a butane cracker, the experiment with high chromium was remembered. Even so, a matter of 0.10% nitrogen was still necessary before the oil chemists' problem could be solved; a 27% chromium-iron with 0.05% nitrogen is so coarse grained it could hardly be worked, whereas one containing 0.14% nitrogen has a velvety fracture, can be pierced and drawn and the tube end upset and threaded without undue trouble. . . . . Many other interesting things can be seen at the Globe plant, among them being a twist test on hot bars from each heat of steel that determines the best temperature for the piercing operation, a semi-automatic draw bench that enables one man to draw more tubes than two men can handle on the conventional equipment (to say nothing of a lubricant that doubles the reduction per draw), and a bright annealer nice and modern in every respect — in fact, ultra modern enough to have its run-in table completely hooded. It seems that a representative of the Wisconsin Industrial Commission had discovered some CO working back from the furnace through the tubes as they were entering, so the table is hooded. . . . . Ihrig's pet gadget for mystifying his visitors is a short piece of shiny metal that is utterly non-magnetic at one end, yet thoroughly magnetic at the other. (Psst! It is an 18-8 bar that has been mistreated at one end to precipitate carbides.)

Was shown about Ampco Metal's shops by George Dreher, plant manager — unusual as a place where they talk about 100,000 psi. strengths in non-ferrous castings, have a modern heat treatment department, and a machine shop doing such accurate work with carbide tipped cutters that 10° difference in temperature will throw the parts off gage. The firm has long specialized on a series of copper-aluminum-iron alloys (aluminum bronzes with unusually high iron and fractional percentages of insoluble elements to "seed" a fine crystallization). The exceptional toughness, fatigue, wear and corrosion resistance of aluminum bronze is secured by close

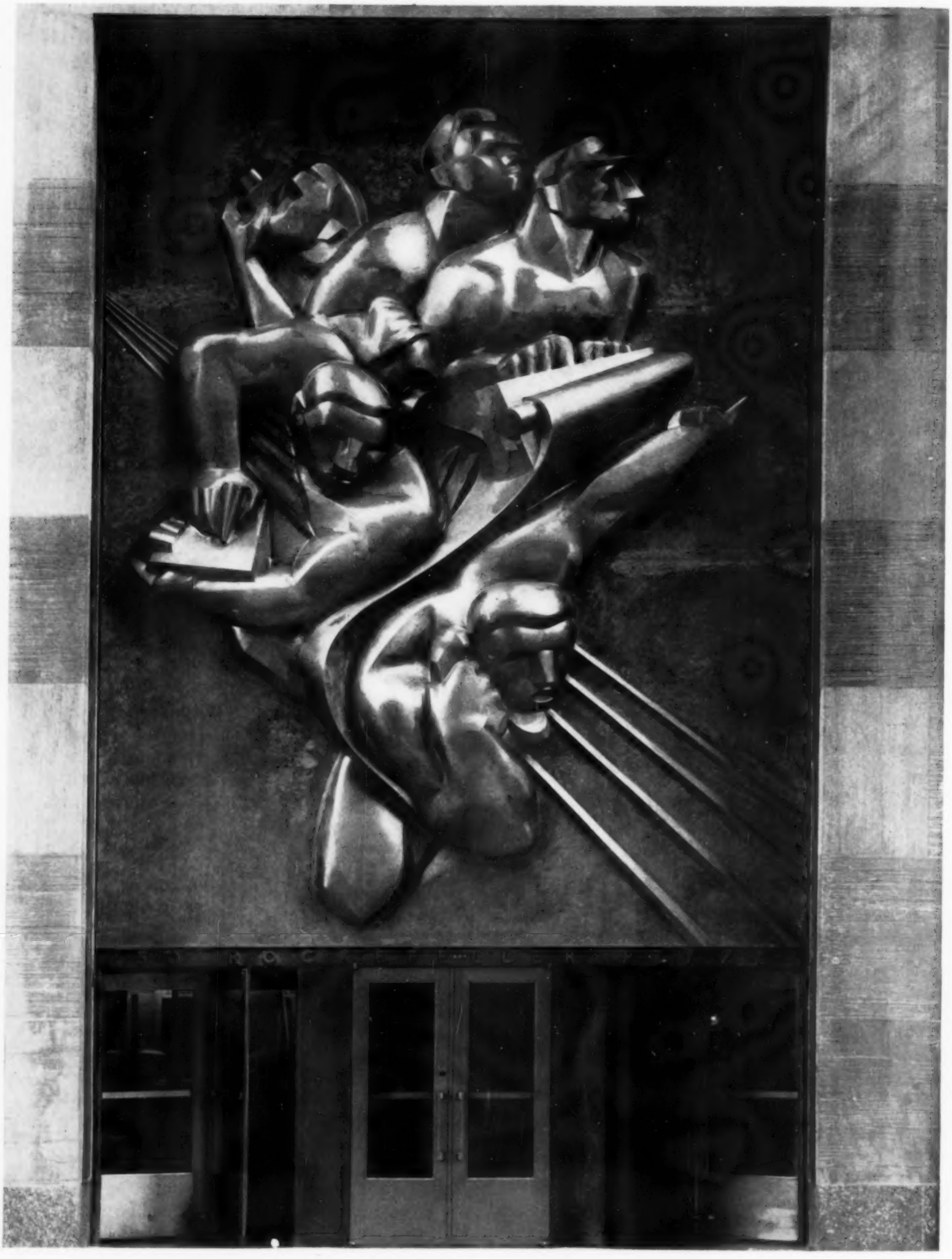
Aluminum Bronzes of Superior Qualities

chemical control of analysis, it being found that slight deficiencies of aluminum may be counteracted by slight increases in iron, or vice versa. A Brinell hardness test on blocks cast in a standardized manner from each melt brings under control one of the traditional difficulties of aluminum bronze — variation in hardness, strength and machinability with variation in analysis, thickness of section, and speed of cooling. . . . . Most interesting was a battery of four centrifugal machines making blade bushings for Hamilton variable pitch air screws. The casting is a hollow tapered cone with a wide flanged base. The permanent iron mold is centered, big end up, in a nicely balanced casing whose top is closed with a breech block having a central opening through which a small ladle-full of bronze is poured. Close control of speed is had by Oil-gear drive; the whole unit is cradled so the axis of rotation may be either vertical or at any inclination (as the size and proportions of the product may require). One furnace man, one ladle man and one valve tender can cast 200 such 10-lb. bushings in a shift. Walter Edens, metallurgist, said that the rapid chill (even when the molds are visibly hot) gives properties and microstructure equivalent to those to be had by 1% additional "hardeners" in sand cast articles of the same size, since the quick cooling prevents the normal amount of transformation of the solid solution existing at high temperatures into the eutectoid existing at low temperatures. The equilibrium diagram and the heat treatments are quite analogous to those of the common iron-carbon alloy known as steel.

Charles Gordon showed me some figures the American Transit Association, of which he is managing director, has assembled from surveys of urban transportation in New York. They make the pictures artists have drawn of the city of the future look rather silly. For instance, the number of people carried in one four-track subway would require a towering tier of 21 four-lane elevated highways to transport in private automobiles. Furthermore, the storage of

Trolley or Automobile

automobiles in the business center requires as much cubage as the room space required by the passengers they carry — that is to say, the fanciful city of the future would be half garage. Likewise a principal surface artery carrying one street car line and two automobile lanes in each direction, interrupted with cross traffic as is now usual, will carry about four times as many passengers as though the street were restricted entirely to private automobiles. Eventual elimination of public transportation (which some visualize) would mean that every citizen would be rich enough to afford the more expensive private vehicles, which may be doubted, for privately acquired information indicates that it costs 70¢ a day to drive to work, 7 miles from home, not counting the cost of storage at both ends, which must be paid for by someone.



Bright New Symbol of America's Free Press

Heroic Plaque Cast by General Alloys Co. From Designs of Isamu Noguchi for Portal of Associated Press Building in Rockefeller Center, New York

By H. H. Harris
President, General Alloys Co.
Boston

Stainless Steel Comes of Age in Architecture

"CAST THY BREAD upon the waters for thou shalt find it after many days" is a Biblical quotation strangely coming to these lips when I look back on the development of stainless steel as a medium for artists.

The predecessors of stainless steel — the heat resisting, high alloys of nickel and chromium — had such unexampled possibilities as an eternal metal that I began thinking "Surely, the artist, the sculptor and the architect would prefer to work in a metal that did not foul its own face" as long as 20 years ago. Then the General Alloys Co. was pioneering in the manufacture of carburizing pots and simple castings of complex alloys for American steel treaters. Those early musings and a lot of "spade work" in architecture, metallurgy and foundry practice have now taken form in the world's first heroic sculpture cast in stainless — a 10-ton bas-relief plaque, called the "bright new symbol of America's free press".

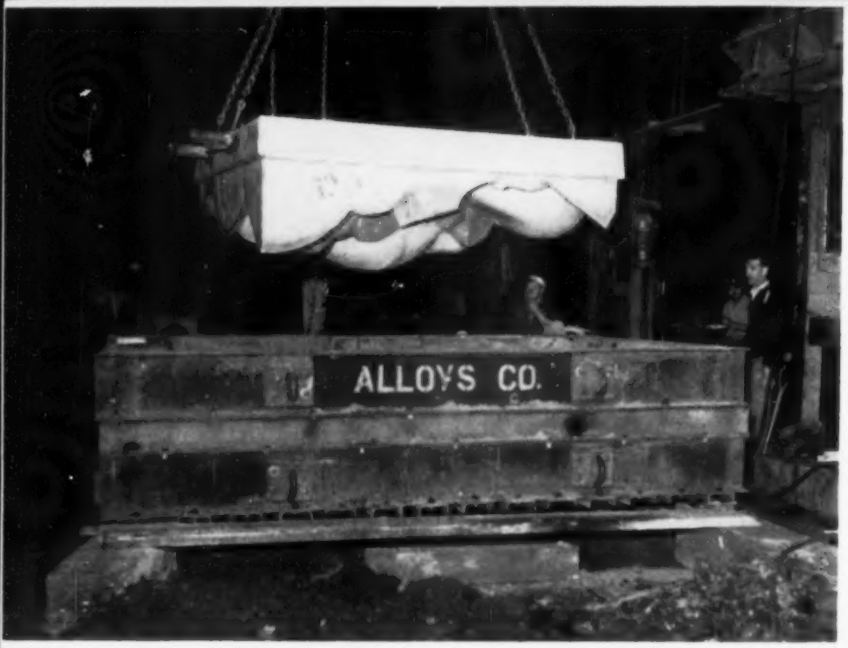
As experience has taught us, it is far more difficult to make perfect castings in these refractory metals of high melting point than it is in the time-honored bronzes of the ancients. Molding methods developed for intricate replicas of ornate models, cast in readily fusible alloys, are entirely inadequate for nickel-chromium-iron alloys. Take the one item of melting point alone. Stainless steel must be cast at temperatures approaching 3000° F.; architectural bronze would be handled at 2000° F. Think of the scour on the sand, and even the excessive shrinkage of the hot metal in the mold, measured in direct proportion to the solidification temperature.

After a few early attempts with small ornamental work it became perfectly apparent that the foundry practices gradually developed for heat and corrosion resisting castings used in industry (some not very lovely to look at, except that the best of them always had the rugged beauty of perfect adaptability for their intended function) would have to be taken over, lock, stock, and barrel, when the real job of casting these beautiful stainless steels in heroic sculpture arrived.

Architects first visualized the decorative possibilities of stainless steel on a large scale. One of the earliest applications was among the largest, used stainless steel sheet exclusively, and remains the most unusual conception. I refer to William Van Alen's design of the Chrysler Building in New York. The gleaming spire "terminating in the empyrean blue", surmounting a peaked roof using a rising sun motif, oft repeated, typifies the everlasting brilliance of the medium. (Unfortunately a few winged radiator caps are hung on for an automotive tie-in.)

Shreve, Lamb and Harmon in using stainless steel sheets for the pilaster covers on their Empire State Building were pioneers in substituting reflected light for ornament — using unbreakable mirrors to accentuate vertical lines.

Neither of these unusual treatments was destined for general adoption. It seemed to me that an even better adaptation of this metal could be made for the spandrels (areas above and below windows in a vertical tier building) of the buildings in Rockefeller Center. The late,



The Drag for One of the Smallest Sections Has Been Rammed With Synthetic Sand, Rolled Over, and the Pattern Is Being Drawn. Pattern is the reinforced section of the sculptor's model

shapes and surfaces, at best, were not truly modeled. Light reflections were distorted as the sheets would spring in and out with temperature changes and wind pressure. Fundamentally, it was wrong to use such a flimsy thickness having little or no mechanical strength for such large areas, despite the fact that the metal, being stainless, was amply durable against weathering.

This tin-smithing of stainless steel was only a stop-gap until Art, temporarily out-distanced by Science, should accept the challenge of Metallurgy and provide aesthetic guidance into Architecture.

After the Cope Is Built up, Largely of Strongly Reinforced and Suspended Cores, 5600 Lb. of Molten Steel Fills Two Basins on Top. At the correct instant, "bath tub plugs" are drawn allowing the metal to rush into the mold through dozens of openings

great Raymond Hood, a principal architect, visualized these possibilities, made some designs, and we made samples of sheet panels mounting cast motifs. However, the immediate manufacture of 22,000 spandrels could not be seriously considered, being far beyond the finishing capacity of the steel mills then capable of making the large polished sheets.

"This new metal should come into architecture through sculpture," said Raymond Hood. It did, slowly and haltingly, using this same thin sheet metal that was quite satisfactory for flat vertical walls, but not nearly so adaptable to intricately curved surfaces. Nevertheless, gargoyles, large symbolic ornaments, and even figures rivaling the Statue of Liberty in size were made by hammering thin sheet into wooden molds, attaching the parts to an interior skeleton, trimming the edges, and joining the pieces by welding or silver soldering. These

Following Raymond Hood's advice, I set about working with promising young American sculptors and casting their work in stainless steel. From Isamu Noguchi — American born of Japanese and American parents — already noted for his departure from art tradition, I got immediate and enthusiastic response. Over a period of years we cast several of his works in stainless steel. Noguchi held a Guggenheim Fellowship for study abroad, was a pupil of Constantin Brancusi, known for his abstractions and studies in dynamic symmetry.

Then came his greatest opportunity, a competition sponsored by Rockefeller Center and the Associated Press for the design of an appropriate plaque for the new Associated Press

Building. This was a most difficult assignment. Throughout history there had been no emblem of journalism, and few such opportunities for great symbolic sculpture.

Noguchi approached his task with pure logic, striving to create a concise and compact symbol of the activity of the press. "It represents to me," Noguchi said, "man's aspiration to the truth and the mechanical means by which, through news, he encompasses the world. Freedom of the press means freedom for all."

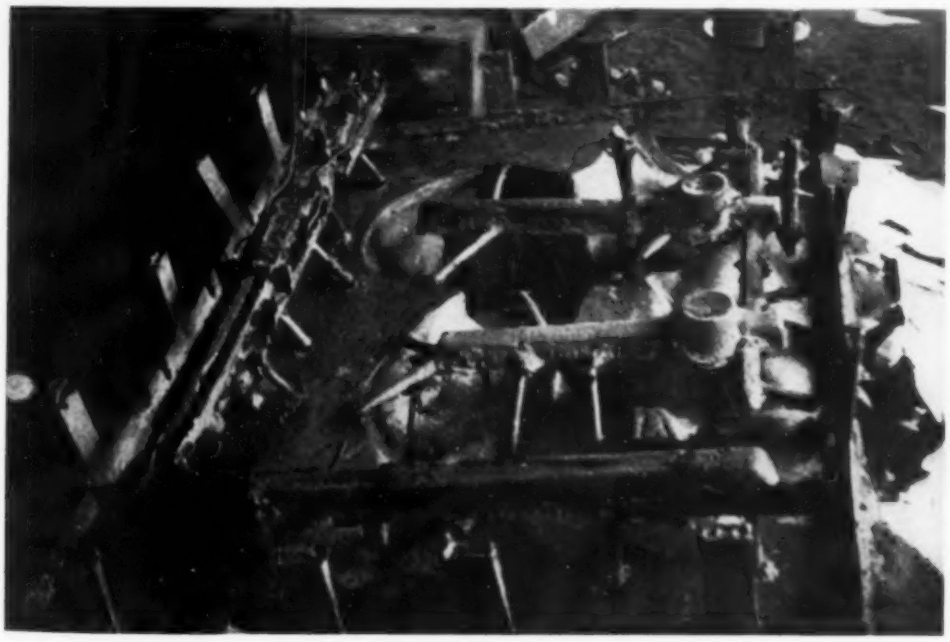
In sweeping lines, he has grouped the figures of five men in one compact flying wedge. Newsmen in action, with the tools of their trade: Four of them are working with the fast action instruments of modern journalism (wirephoto, teletype, camera and telephone) while one carries the pad and pencil, trademark of all reporters. The panel was designed with a most penetrating insight into the very essence of journalism.

The competition won, and even though the terms of the competition specified a bronze plaque, Noguchi was and had been for eight years thinking of steel. He said to the Rockefellers, "I am proud, but I will be prouder still if my work can be executed in stainless steel." To their credit it must be said that they gave ready response, even realizing that nothing like it had ever before been done. (Many things never before done have been done in Rockefeller Center.)

As William Van Alen writes in "The Book of Stainless Steels": "Production of architectural castings of any metal is a highly specialized foundry problem. When working with the stainless alloys, the difficulties are heightened by the sluggishness, infusibility, and high shrinkage of the metal. It must be remembered that such forms as the round sections and undercut leaves of ivy or oak, so often encountered in stone or plaster, are not easily executed in cast metal. Ornament in the latter medium therefore consists in a studied arrangement of incised and raised members, and dull and polished surfaces."

Judged by the above criteria, Noguchi's design was eminently suited to production in steel. Its foundry problems, it seemed to us, were more related to the *area* of the castings than to any of the other details we had satisfactorily solved in 22 years of work with the corrosion and heat resisting steels and alloys. While we have never actively solicited architectural business, we frequently cast sculpture to emphasize our foundry arts, and have exhibited them for the past 20 years at the National Metal Expositions. I had promised Noguchi nearly eight years ago, "Whatever you do in sculpture, we will execute for you in stainless." We therefore asked Rockefeller Center for the opportunity of casting Noguchi's plaque in stainless steel. They agreed in principle, and sought to find competition for us. There was none offered. The "experts" shook their heads. "It couldn't be done!"

The pattern from which this plaque was cast was the full scale, 18x23-ft. plaster model, enlarged by Noguchi from his original eighth-size model with which he won the Rockefeller award. A great deal of study of the artistic requirements and technical limitations was necessary to determine the number of sections in which to cast the plaque. It was eventually made in nine sections, the largest one weighing over two tons, and the smallest approximately 1200 lb.



Rear View of One of the Small Sections, After Shaking Out of Mold, With Sand and Multiplicity of Gates Still Adhering

Allowance for casting shrinkage had been made in the dimensions of the full scale model, but the thickness and width of the sections had to be increased over the original dimensions to allow for machining and contouring. The plaster model-pattern, made on wooden armatures, had to be heavily reinforced in steel and cement before it could be used as patterns, to stand the weight and extra hard packing of a special synthetic sand into the drag, rammed hard with air rammers.

The face of the sculpture was cast in the drag. The cores forming most of the cope were all built on heavy steel armature-arbors welded from tubes and rods, many incorporating refractory runners. They were suspended through the cope by adjustable steel hangers from steel framework attached to the heavily constructed steel flasks. Pick-out pieces were ingeniously locked into the mold. No chaplets were employed. All registrations were maintained by adjustable steel connections, core prints not being relied upon to maintain alignment when pouring such light sections.

Because of the cutting action of large quantities of molten metal at the high pouring temperatures (approximately 3000° F.) it was desired to avoid washing molten metal over any large area. Therefore, as many as 80 different gates — in some sections as many as one to the square foot — were employed. Molten metal was fed into these gates from reservoirs on top of the molds, equipped with plug valves that provided instant and simultaneous release of metal, so that the mold was filled in one second by a surge of metal. The larger sections were poured simultaneously with two ladles, the largest amount of metal being poured at any one time being 5600 lb. The metal itself is a super stainless of the 24% chromium, 12% nickel type. Special ladles with straining devices in the pouring spout prevented slag from entering the mold. Slag traps were also employed in the gating. Gates were later removed with diamond-toothed saws.

Meticulous care in calculating the shinkage and strains over widely varied angles and contours when casting different sections at different times, entirely different in form except for their matching edges, enabled them to match to less than 0.10 in. Shrinkage from molten to cold state is over ¼ in. per ft., and some of the contoured edges totaled more than 25 ft. The flat sections shrink at one rate, and the curved sections at varying rates.

Putting on the Finishing Touches After Erection. The sculptor personally finished most of the surface by grinding in a skillfully studied variety of angles, to disperse glaring light reflections

The secret of the shrinkage control is the uniform temperature of each portion of the metal in the molds, filled almost instantly. This is an entirely new approach to foundry problems, but had been originally developed by us when making some large and difficult castings for the U. S. Navy.

Because the high localized temperature of welded joints would result in excessive warpage it was deemed inadvisable to weld. The nine sections were joined into three horizontal units by machining the edges to match to 0.002 in., forming a practically invisible line, and then doweling and bolting from the rear of the plaque. The entire plaque is carried on one horizontal I-beam, running across its center line horizontally, riveted to the portal structure at either end, and requires no other reinforcement. Due to the great strength and hardness of this metal, it was not even crated for shipment; there is no "surface finish" to be scratched, and nothing to rub off.

It was originally decided to finish this plaque with a high *(Continued on page 586)*

Photographed by
Van Fisher
at LaBelle Works,
Crucible Steel Co. of America
Pittsburgh, Pa.

Crucible Steel

Made in America

The Steel Maker

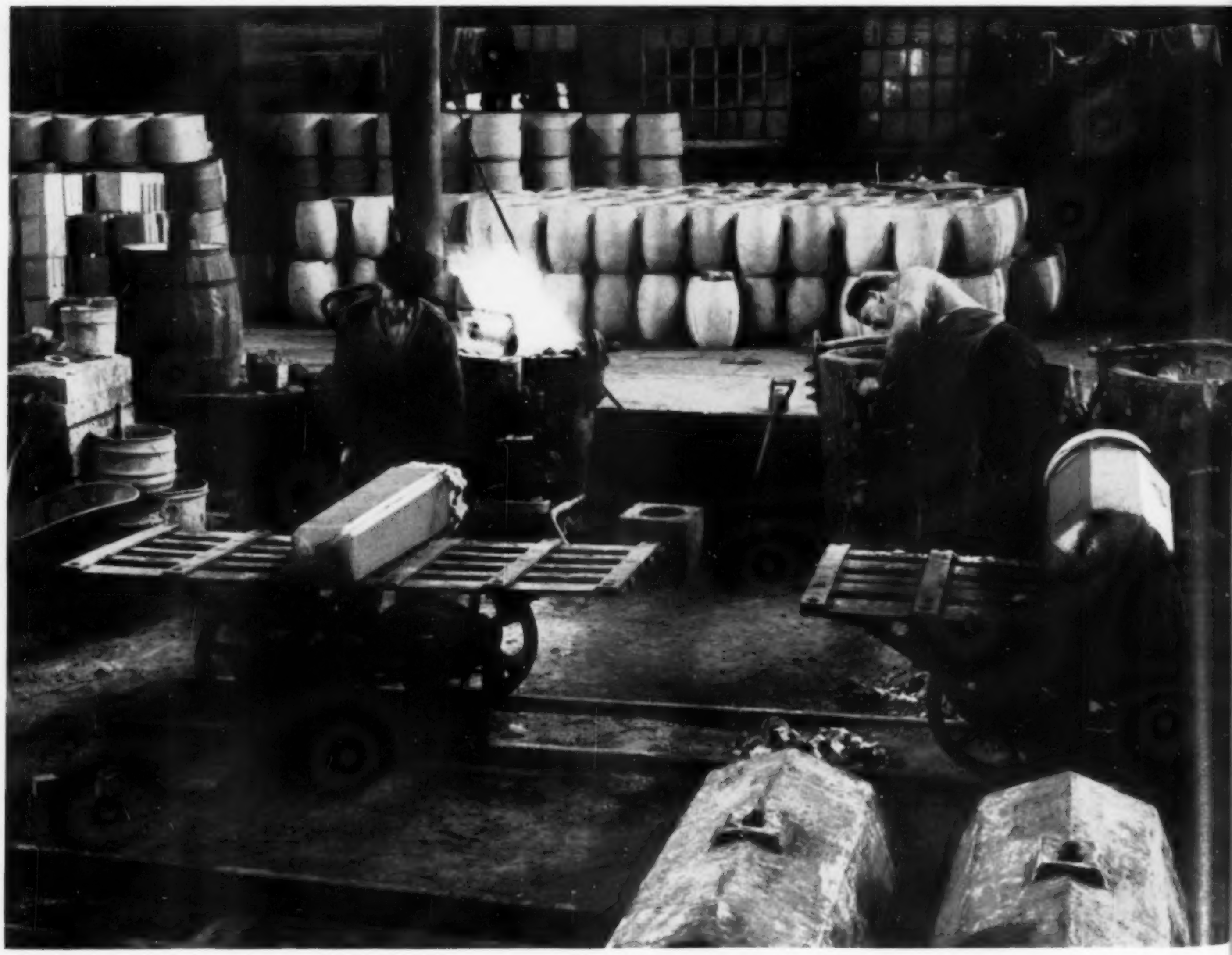
MANUFACTURE of crucible steel, invented by Benjamin Huntsman just two centuries ago, is almost extinct in America, yet this steel, like old wine, has a subtle body. Harry Brearley says, in his fascinating book "Steel Makers" (the manufacture of crucible steel in the Sheffield tradition):

"Tools are still being made for which the best possible steel is required and for which cost of production of the steel is a detail. The maker of such tools may in time forget that what he is getting is only second rate because the method of making first rate toolsteel is thought to be too expensive. . . . I fancy that within 50 years of its disappearance, if it should be eliminated, some enterprising maker of fine tools will rediscover the worth of pot steel and live over again the experience of Benjamin Huntsman."

This quotation, together with others on later pages, is by kind permission of the author, Harry Brearley.

RAW MATERIAL used by Huntsman, on his invention of crucible melting about 1740 — just two centuries ago — was probably the raw material for tool making prior to that time, namely carburized Swedish bar iron or "blister bar". A few generations after, some steel maker, greatly daring, melted together a mixture of Swedish wrought iron and charcoal to produce steel. Raw material is still selected with the greatest of care, but by analysis rather than tradition. It consists of muck iron, remelting bar, selected plate scrap — all sheared into small pieces and assembled in weigh-pans so 100 lb. can be packed into a single crucible. A little ground glass is added for flux, and enough "medicine" to bring the eventual steel to the desired analysis — charcoal, carbon, nickel, and ferros containing silicon, manganese, chromium and vanadium.

Traditionally pots were made of clay, kneaded with bare feet and shaped and dried at the furnace into a fragile container for a 60-lb. charge. Coke dust or charcoal in the mixture has given way to flake graphite, an ingredient that strengthens the larger modern crucible against successive heatings and coolings. When making hand-teemed ingots weighing 100 to 200 lb. the crucibles last 12 to 15 heats; ladle poured ingots require hotter steel and 7 to 8 heats is then an average life.



THIS crucible melting shop, the sole remaining in the United States, contains a 30-pot furnace — 5 holes, 6 pots to each hole. Its fuel is natural gas, the draft controlled by stack dampers. During melting the gas is reversed in each hole by its own valves every 20 to 30 min.; after melting the reversals are twice as often. The floor is quiescent during the three hours required for melting; the only activities are auxiliary, such as weighing up the charges, and work by the two molders in the casting pit. They clean and preheat the ladles, make new stopper rods, clean and assemble the split molds, preheat them slightly, reek them with resin, and place the dozzles. Writes Brearley of the topping of ingots down to pipe-free metal "which involved a waste of at least 20% of the ingot's weight: It needed nearly 150 years to discover that the waste could be avoided by placing a heated fireclay sleeve, called a dozzle, into the top of the ingot mold to keep the upper portion of the steel fluid enough to feed the cavity (pipe) formed by shrinkage as the ingot itself passed from the liquid to the solid condition. . . . The names of the men who introduced the dozzle and the taper mold set wide end up should be recorded in the annals of steel making, but they appear to be unknown."

BEFORE each set of new pots is placed in the furnace, the old bottom is cleaned out through a 6-in. opening in the bottom of each hole—hot work, done quickly by the two pullers-out and the teemer. The opening is then sealed with an old cap and the furnace bottom covered with an 8-in. layer of fine coke breeze which not only serves as a cushion when lowering the pots, but keeps them up off the brick floor into the zone of more uniform heat. . . . Bottoms of old crucibles are removed by a cap cutting machine and are used as covers. . . . The weight of one pull is crucible 40 lb., charge 100 lb., cap 5 lb., tongs 20 lb., a total of 160 lb.

SOME three hours after the firing begins the charge is melted. To make sure of this, the melter feels for solids in each pot and judges its temperature by moving the cover slightly and using a "looking stick" — merely a rod of low carbon steel. If everything is correct the charge is then given about 45 min. more heat for killing or dead melting. During this period final traces of rust from the charge and oxides formed during melting are reduced by reaction with the silica or graphite in the pot wall. The amount of silicon and carbon picked up from this source varies with time and temperature, and the composition of the finished steel is in this respect under the control of the melter. Practically no chromium, vanadium or other oxidizable alloys are lost from the charge; ferromanganese for high manganese steels is added late in this killing heat, to avoid its scouring the crucible at the slag line.

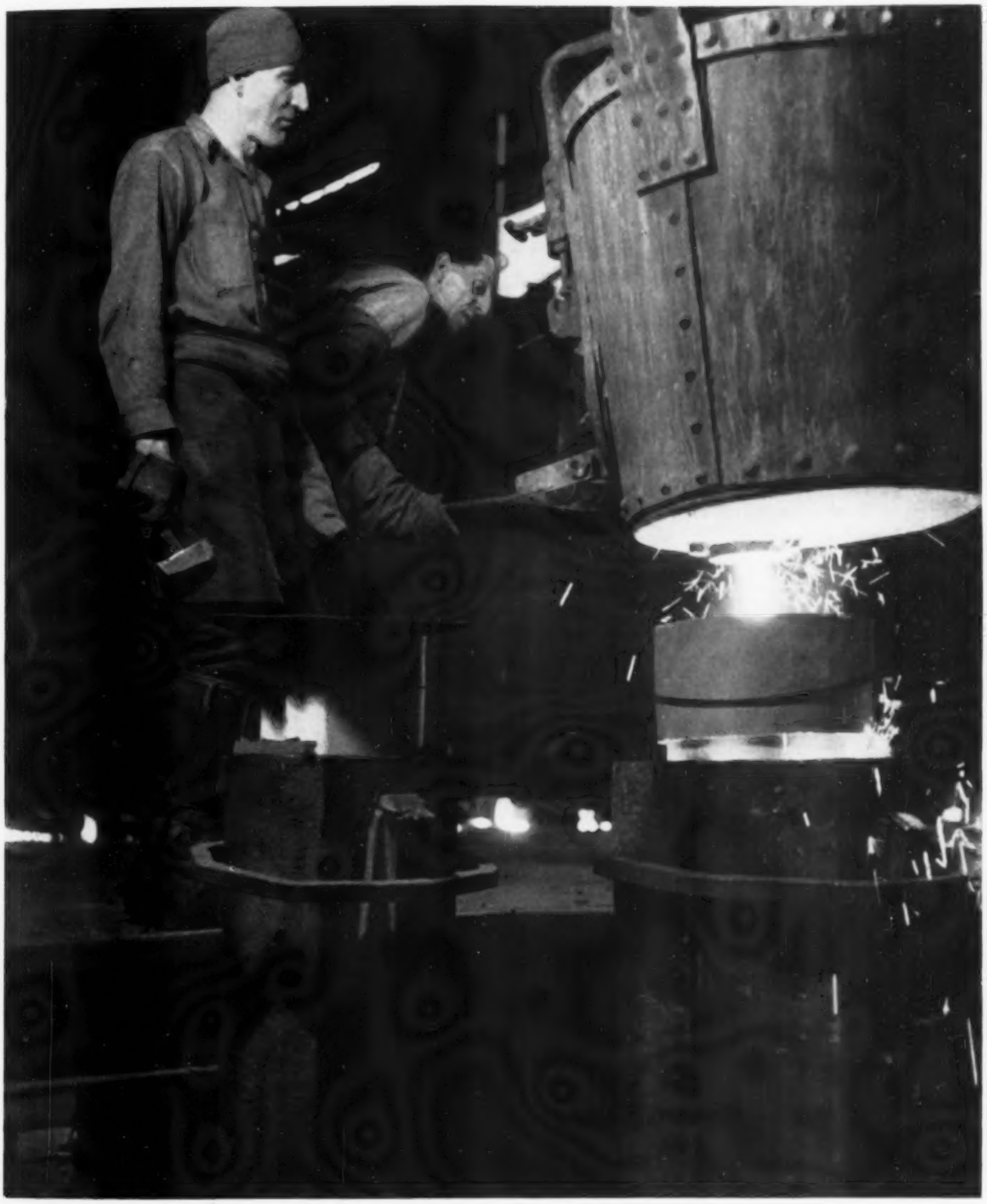
"EXCEPT weighing up the charges for the next heat the melter has only a supervisory job until the steel is melted and ready for casting; then he is the Shah of Persia, and everything which is not done by rote is done to his bidding. Like the puller-out, the lower parts of his legs are protected by sacking laid onto a foundation of tarpaulin or some other waterproof stuff. These trappings are called 'rags', and none will dispute the fitness of the name who sees them surmounted by a stout sacking apron reaching to the knee, the entire outfit, as well as the handbags, dripping with water." Thus Brearley describes the Sheffield steel maker of his youth. In this American shop in 1940 even their footwear is traditional, clogs with 2-in. wooden soles — except they have stainless steel plates on the bottom.

"IT goes without saying that a man who can lift a pot containing 100 lb. of molten steel with a pair of heavy tongs from a furnace below ground level at a dazzling white heat is no weakling. I say 'lift', but the pot is not lifted; to call the men 'lifters' instead of 'pullers-out' would be insulting. The actual pulling out is like Macbeth's job: 'When 'tis done, then 'twere well it were done quickly.' . . . . . At steel melting heat the pot is soft and in a degree yielding. The puller-out can feel the 'give' of the pot when his tongs grip it. The feeling of 'give' gives him confidence to straighten his back and with an unbroken pull and swing to set the pot on the floor-plates. His ends of the tongs are held together by his hands only; he might use a ring to hold them together, but by doing so his sense of feeling would disappear, and the contact between him and the pot be less intimate."

"THE puller-out has swung the pot of molten steel across the floor and removed the lid. The teemer holds the pot in his bowed tongs, which grip it generally about midway, but specifically where he is likely to be most satisfied when the loaded tongs are balanced on his knee. . . . . The teemer is generally big and strong, but as he is no longer young he may be rather fat, and has generally a ruddy face. His gait is slow, as befits a man who for a generation has done heavy physical work. . . . . Watch him teem, and the physical grace of the bulky man and the play of color around the pot enchant you. . . . . From the bowed ends of the tongs which grip the pot, long shanks pass over the knee of the crouching teemer and extend as far as his left arm can comfortably reach. No lady, handling a delicate china cup, ever sipped tea with greater niceness than the knowing melter delivers the glistening stream of molten steel."

STEELING — that is, filling the pot with new charge — is immediate after the pot is teemed. In the old practice the clay crucible was replaced in the hot furnace as soon as possible, and the charge was funneled down a trough into it. Now the graphite crucibles, which can stand being cooled without cracking, are slid over to one side of the floor, placed on a shaker, and the charge joggled down until the cover will fit.

AFTER steeling, the crucibles are trundled over to the furnace by one of the molders to be lowered into place. "By this time the puller-out, more than any other man in the gang, is soaked with sweat from top to toe. By all accounts this is the time when a couple of pints of beer will fill most tastily a long-felt want; and when men had the freedom of the works gates one could tell by the goings and comings, but particularly by the goings, how the operations stood."



TEEMING of 1000 and 2000-lb. ingots is from the ladle. (Larger ingots are now preferred for medium to large size bars, since hand-teemed ingots of 200 lb. would be insufficiently reduced by forging.) As soon as the metal solidifies, the wedges are loosened and the rings removed, and the hot ingots immediately buried in coke dust or ashes, so as to cool slowly and uniformly and free from contraction stresses. Each ingot is analyzed, reheated, saddened under the big steam hammer, and reduced to billets and bars by the accepted high quality methods of a modern toolsteel mill. At present the main demand for American crucible steel is for various cold working dies for heading, striking, coining and swaging.

Aluminum Alloys for Bearings

By W. C. Devereux

Abstracted from Journal *of the British Institution of Automobile Engineers February 1938, page 54*

BEARINGS in high power engines, as for aircraft, motor boats and racing cars, are generally of the more expensive lead-bronze rather than tin-base white metals. Unexpected variations in their life have warranted intensive study of all factors surrounding the service, and among these are the possibilities of aluminum alloy bearings. At first sight it would appear to be a simple matter, as almost all binary alloys of an added element to aluminum giving a eutectic and low solid solubility show the accepted "bearing structure" of a hard constituent in a soft matrix, and have suitable hardness ranges. However, it is not as simple as that.

During the World War some recommendations were made by the Royal Aircraft Establishment, but these alloys would not carry loads above 500 psi., and invariably seized when lubrication failed. Later experiments with aluminum-copper and aluminum-silicon types indicated that the bearings were very sensitive to edge pressure, and although the correct microstructure was present, the hard constituents were torn out during machining, and the soft matrix smeared unless diamond tools were used.

However, this type of alloy is being developed in Germany with alloys such as Quarzal Q 5 and K.S. 280 (see the accompanying table for analyses). K.S. 280 is 120 Brinell hard, has a coefficient of expansion of 17×10^{-6} (this being somewhat offset by a low thermal conductivity), and a comparatively low coefficient of friction. It has been used satisfactorily with specially hardened polished shafts, clean oil, exact and large clearances, and insertion of an elastic medium into the joints of highly stressed split bearings.

Junkers has developed a new bearing for which satisfactory results were claimed in 1936. A special technique has been evolved to overcome the difficulties of casting and forging inherent in alloys of this composition. With diamond turned bearings, surface loads could be increased until plastic deformation occurred. Dirty oil caused small scratches but no abrasions. When lubrication was cut off, the bearings would run for about 10 min. as against 15 min. with babbitt.

In England Rolls-Royce, working in conjunction with High Duty Alloys, Ltd., has developed a series of bearing alloys which gave excellent results on service tests on the big-end and main bearings of Rolls-Royce and Bentley engines. They are now the only cast light alloy bearings successfully applied as a standard component. This alloy contains a variety of constituents of widely differing hardness forming a mosaic which will not be torn out during machining nor yet pierce the oil film under poor lubrication. Correct additions have to be made to the solid solution matrix to produce an optimum hardness value to prevent seizure on soft shafts.

The following comparative tests may be quoted for three Rolls-Royce Kestrel aero engines having nickel-chromium steel crankshafts 302 Brinell hard. One had light alloy bearings A.C. 7 (90% aluminum, the remainder being carefully controlled proportions of tin, antimony, nickel, manganese, and silicon). The second had babbitt bearings and the third a 28% lead-bronze.

All three engines were "run in" for 2 hr. at 1000, 1300, and 1700 r.p.m. at 160° F., the speed then being reduced to 1000 r.p.m. and the test proper started. The speed and load in psi. were then increased alternately at 15-min. intervals by 200 r.p.m. and 200 psi. respectively on the Thurston bearing testing machine. Amperage readings gave the relative bearing properties and showed that at all speeds and pressures up to 2800 r.p.m. and 2400 psi. the aluminum base alloy A.C. 7 has a lower friction coefficient than the other two bearing materials.

Analyses of Aluminum Alloy Bearings

	Q 5	K.S. 280	Junkers	RR. 56
Cu	5	1.5		2
Si		21		0.6
Mg		0.5	0.5	0.8
Fe	1		6	1.2
Ni		1.5		1.3
Co		1.2		
Mn		0.6		
Ti				0.07

An English manufacturer of heavy trucks has replaced lead-bronze with "Hiduminium RR. 56" bearings. He reports such tests as the following on a 6-cylinder engine equipped with three RR. 56 big-end bearings and three A.C. 7 bearings: While the oil supply was gradually reduced until seizure occurred, the oil pressure had to be reduced to zero before one of the big-end bearings seized. The remaining five were found to be in quite good condition. From the results of such tests it was concluded that with either RR. 56 (specially treated) or A.C. 7 bearing, fitted at a running clearance of 0.0008 in. per in. of crankpin diameter, exceedingly severe treatment has to be given to the engine before anything serious happens to the aluminum alloy bearings.

By Walter A. Dean*
Aluminum Company of America
Cleveland

Tools and Speeds for Machining Aluminum Alloys

"MACHINABILITY IS THAT PROPERTY of a substance which permits it to be formed into a finished product by the removal of excess material with a cutting tool." This definition, like all others, is open to the criticism that it fails to describe the nature of machinability; however, it is adequate for the present article which is devoted to commercial processes for machining aluminum alloy forgings and castings. A general description of the alloys themselves and a classification into various types has been printed in the February issue. Alloys of Type I have excellent machining properties, Type II have good machining properties, Type III require special care to machine satisfactorily.

Turning — The lathe operator in many machine shops determines the rake angles, clearance, shape of tip, and the way the tool is set in its holder; consequently turning tools of widely different designs are in actual use. Experience with aluminum alloys has shown, however, that the cutting edge should be well cleared all around, finished with a fine stone or buffed, and set above the center line of the work.

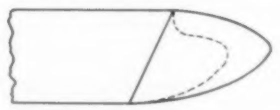
The same tool may be used for roughing and finishing but it should be redressed between the two operations. The tool in the first sketch on page 554 is suggested for jobs of a miscellaneous nature. When machining one of the free-cutting alloys the rake angles may be decreased; such a more rugged and longer lived tool is recommended also where the cutting edge is excessively abused, for example, when machining castings or forgings with lugs or bosses, or when removing the outside surface of a casting. If the material is gummy the rake angles, particularly top-side rake, should be increased. The point may be rounded and where a fine finish is required the heel of the point may be allowed to drag on the work. Rake and clearance angles of tools tipped with cemented carbide should be kept at a minimum consistent with satisfactory finish, so as to provide maximum support for the point. Sturdy construction of tools and holders is essential to minimize vibration at the high speeds at which aluminum alloys are turned. A solid shank should be used for heavy roughing cuts.

Turning speeds, feeds and cuts for aluminum alloys are shown in the table on page 554.

Milling — Aluminum alloy forgings and castings are machined satisfactorily with milling cutters of the inserted or solid tooth type. A design of blade for the inserted type is shown at the top of page 555. Cutters are inclined to the work at an angle of 60 to 70° to prevent chatter and to increase the shearing action of the tool. The leading corner is bevelled as much as 45° for rough milling and as little as 3° for finishing on a smooth surface. The cutting edge should be cleared 1 to 2°. A clearance of 0.003 to 0.005 in. at ⅛ in. back of the cutting edge may be increased beyond this point at an angle of 5 to 7°. Greater clearance is usually unnecessary and only weakens the tool. A gen-

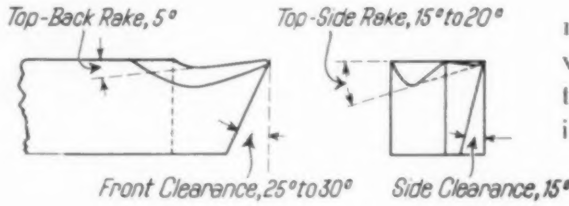
*The wide practical experience of the men at the Cleveland Plant of the Aluminum Company of America, particularly Messrs. O. Jackson, A. Campula and D. O'Donnell, was available to the author. He acknowledges his indebtedness to them.

eral rule, however, is to relieve the cutting edge until back drag just disappears.



Same Turning Tool (for Armstrong Tool Holder) May Take Both the Roughing and Finishing Cuts, Refinished on a Fine Stone and Buffed Between the Two Operations

Heavy duty, spiral, solid tooth milling cutters, and special cutters of this general type with a large helix angle, perform very well. The latter is a very free-cutting tool and is particularly recommended for intermittent cuts — that is, where a series of bosses are to be milled. Side milling cutters with alternate right and left helix are free-cutting and can be used at high feeds. End, straddle and similar cutters should be of the coarse tooth, spiral type with notched teeth to assist in breaking up the chips.



All cutters should have a coarse spacing of teeth to increase chip room and to reduce the number of tooth engagements at any one instant which, in turn, decreases the thrust on the tool. Where expensive fine tooth milling cutters are available they work better if every other blade is removed or every other tooth ground out.

Speeds, feeds and cuts for milling aluminum alloys are shown in the table. The feed may be heavier the larger the cutter used, the heavier the casting or forging and the more securely it is anchored. To prevent the occurrence of low spots, the work should be at room temperature when finishing cuts are made.

To dissipate heat generated during milling, a cutting compound which is a good coolant, such as soluble oil, is generally used.

Boring — The speeds at which aluminum alloys can be bored are limited frequently by the condition or maximum speed of the machine. Speeds, feeds and cuts for light duty and heavy duty equipment are shown in the table at the bottom of this page.

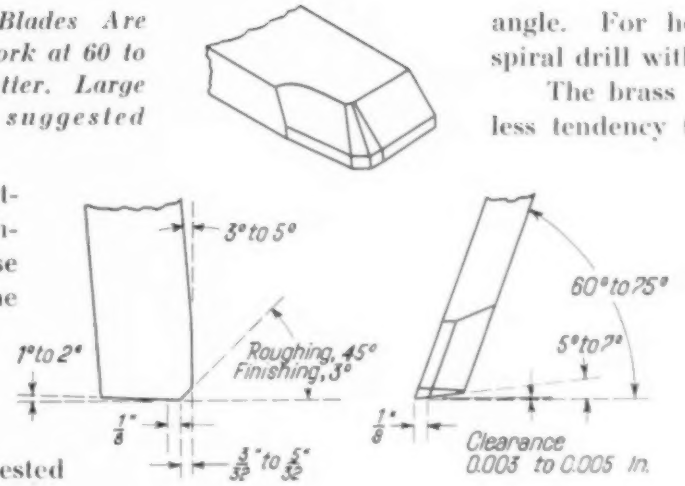
Planing and Shaping — Inertia of the table or the ram limits the speed at which aluminum alloys can be cut in the planer or shaper. The work generally can be anchored securely; consequently heavy feeds and cuts can be taken, which to some extent compensate for the low permissible cutting speed. The planing or shaping tool for roughing should cut almost entirely on its side. Such a tool is shown in the lower figure opposite. Finishing cuts are taken

Cuts, Speeds and Feeds When Machining Aluminum Alloys

	Rough Machining			Finish Machining		
	Cut (In.)	Speed (Ft. per Min.)	Feed (In.)	Cut (In.)	Speed (Ft. per Min.)	Feed (In.)
Lathe turning						
Type I castings, not heat treated	<0.25 *(a)*	500 to 900	0.020 to 0.030	0.002 to 0.010	Maximum	0.002 to 0.010
All others	< 3/16	400 to 800	0.007 to 0.020	0.002 to 0.010	600 to 900	0.002 to 0.010
Milling						
Type I castings, not heat treated	<0.25	400 to 600 *(b)* 500 to 700 *(c)* Maximum *(d)*	5 to 15 *(e)*	0.010 to 0.020	500 to 700 *(b)* 500 to 700 *(c)* Maximum *(d)*	10 to 25 *(e)*
Type I castings heat treated; Type II castings; Types I and II wrought alloys, heat treated	<0.25	(for milling all alloys except Type III)	4 to 10 *(e)*	0.010 to 0.020	(for milling all alloys except Type III)	5 to 15 *(e)*
Type III alloys	<0.25	300 to 500 *(b)*	3 to 8 *(e)*	0.010 to 0.020	500 to 700 *(b)*	4 to 10 *(e)*
Boring						
Light duty (1 to 2 in.)	< 1/32 *(a)*	Maximum *(f)*	0.010 to 0.020	0.010 to 0.020 *(a)*	Maximum *(f)*	0.001 to 0.005
Medium to heavy duty	< ¼ *(a)*	600 to 1000	0.007 to 0.015	0.010 to 0.020 *(a)*	600 to 1000	0.001 to 0.003
Shaping						
Heavy duty (36 in.)	<0.25	Maximum *(g)*	0.010 to 0.030	0.005 to 0.010	Maximum *(g)*	0.100 to 0.150
Planing	< 3/8	Maximum *(h)*	0.025 to 0.100	0.005 to 0.015	Maximum *(h)*	0.050 to 0.375

Notes: *(a)* Cut measured on radius. *(b)* For carbon steel tools. *(c)* For high speed steel tools. *(d)* For cemented carbide tools. *(e)* Travel of work. *(f)* Peripheral speed of tool is maximum of most machines. *(g)* Travel of ram. *(h)* Speed of table.

Milling Cutter Blades Are Inclined to the Work at 60 to 70° to Prevent Chatter. Large helix angles are suggested



with the front or bottom edge of the finishing tool and, because of its broad shape, the feeds are very large. Feeds and cuts at the maximum speed of the equipment are suggested in the table (page 551).

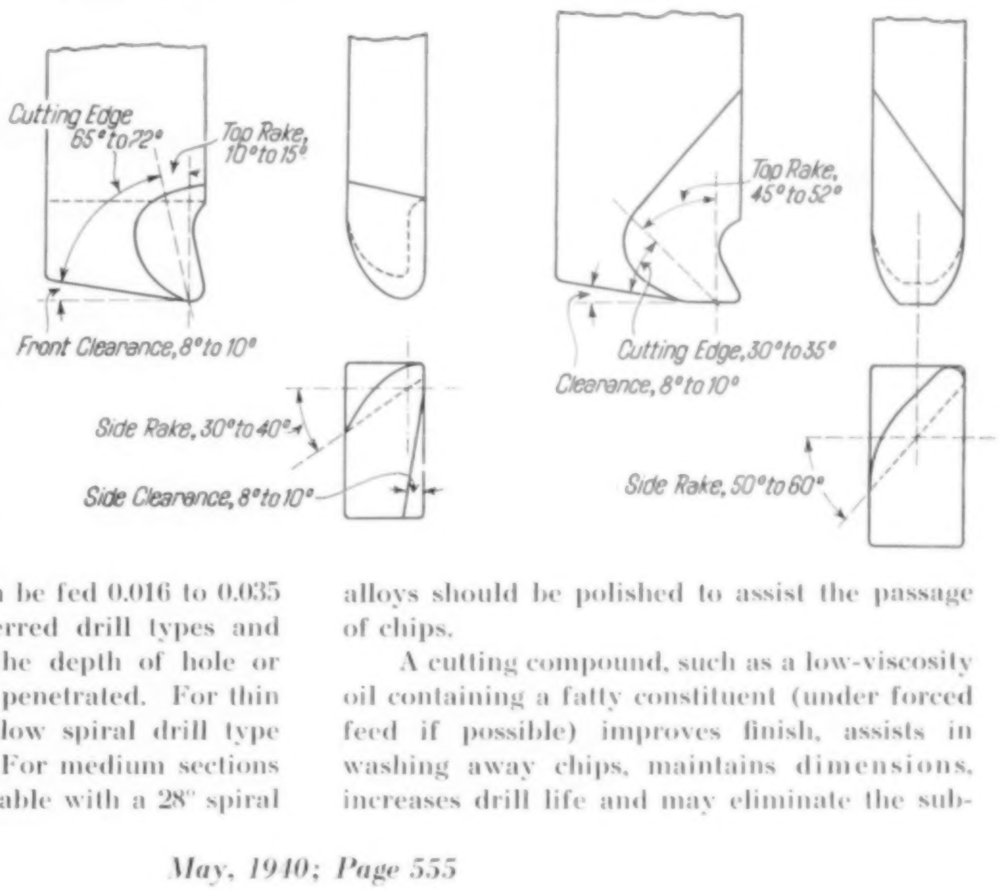
Drilling—Limitations in equipment prevent the use of optimum cutting speeds when drilling small holes; thus, a 1/8-in. hole drilled at 200 ft. per min. requires a tool speed of 6000 r.p.m. Small holes in aluminum alloy castings or forgings, therefore, are drilled at the highest speed the equipment will stand. Under these conditions, carbon steel drills frequently are used at a saving in tool cost; otherwise high speed steel drills are recommended. While the latter drills run at the same speed as carbon steel drills they can be operated at considerably higher feeds. Heavier drill feeds are permissible in aluminum alloys compared to the heavier metals because of the lower axial thrust on the tool.

Speeds for drilling aluminum forgings and castings range up to 600 ft. per min. Feeds for high speed steel drills of whatever type increase with their diameter; for instance 0.001 to 0.012 in. per revolution will be proper when making small holes up to 3/8 in. diameter in medium sections; 0.006 to 0.020 in. can be taken with drills of 3/8 to 1 1/4 in. diameter; larger drills can be fed 0.016 to 0.035 in. per revolution. Preferred drill types and spiral angles vary with the depth of hole or thickness of section being penetrated. For thin sections use a brass or slow spiral drill type with spiral angle of 24°. For medium sections a regular drill type is suitable with a 28° spiral angle. For heavy sections use a high spiral drill with 37° spiral angle.

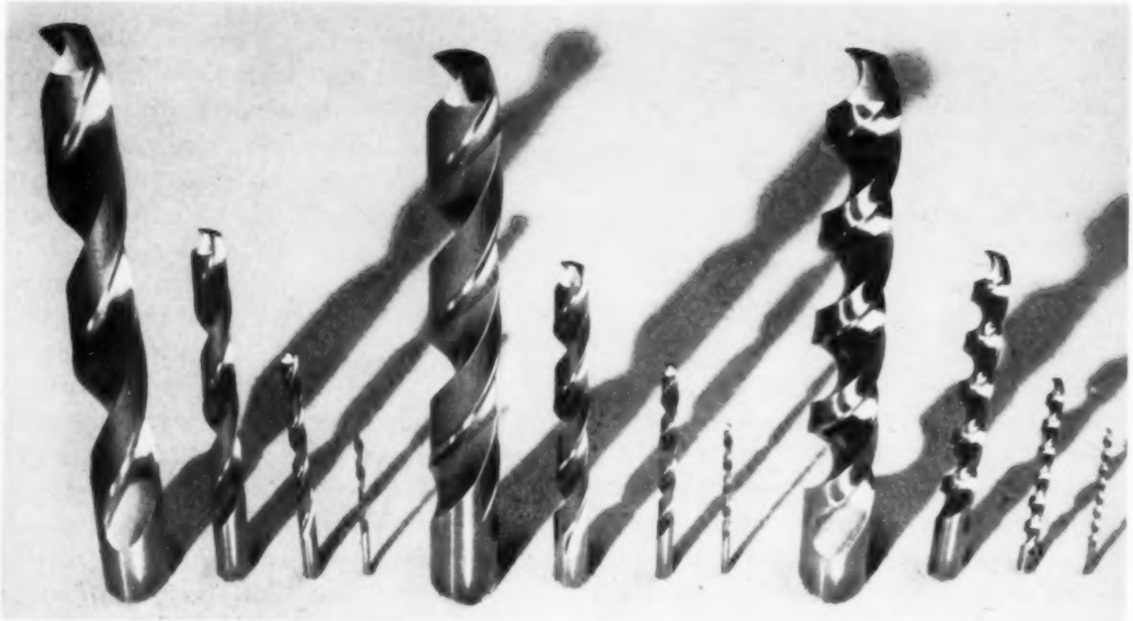
The brass or slow spiral drill shows less tendency to run ahead or "hog in" and therefore performs well in thin stock. The high spiral drill, for deep holes, has narrow lands and margins and greater depth of clearance which prevents build-up of chips on the tool. Spiral drills are preferred for vertical set-ups where the tool revolves, but for horizontal operations where the work revolves it will be found that straight fluted drills frequently perform better.

The standard point angle of about 59° supplied by drill manufacturers is satisfactory for most jobs. The lip clearance of 12 to 15° may be increased, particularly when the feed is heavy or when drilling the gummy type alloys. As the drill is shortened by redressing, the point should be thinned; if this is not done greater pressures are required to maintain the same feed, the work becomes overheated and the hole is off size. Flutes of all drills used in aluminum alloys should be polished to assist the passage of chips.

Planer Tool for Roughing (Left) Cuts Almost Entirely on Its Side. Finishing tool (right) is broad and cuts with the front or bottom edge



A cutting compound, such as a low-viscosity oil containing a fatty constituent (under forced feed if possible) improves finish, assists in washing away chips, maintains dimensions, increases drill life and may eliminate the sub-



Drills for Aluminum Alloys Have an Increasing Spiral Angle as the Depth of Hole or Thickness of Section Increases. Polished flutes clear the chips better

sequent use of a reamer. When drilling deep holes the tool should often be completely withdrawn to make sure the lubricant reaches the bottom. During deep drilling the work should be generously sprayed (cooled).

If drills break frequently the trouble may be caused by lack of rigidity in machine or work, the use of an excessive feed particularly when drilling shallow holes, or insufficient lip clearance. Because drilling speeds in aluminum alloys are high it may be necessary to warm up the drill slowly by starting at a moderate speed which can be increased gradually.

Tapping and Threading — Gun, spiral and standard taps with polished flutes are used in aluminum alloys. The gun type, which curls the chip ahead of the tool, is designed for through holes or blind holes that are deep enough for the chips to collect at the bottom. The right hand spiral fluted tap performs well in blind holes, for the tool guides the chips away from the bottom. Standard taps will be found to be quite satisfactory for aluminum alloys of Types I and II, while spiral fluted taps may be used in any of the alloys. One with staggered or interrupted threads works well in the gummy alloys of Type III. American National, American Standard, National Acme, and Whitworth threads are preferred because of their flat or rounded tops and bottoms. A sharp V-thread should be avoided.

Ample hook on the leading edges of the tap will assist in clearing chips and produce smoother threads. A hook on the back of the lands prevents tearing when removing the tap from the work. A chamfer on the first three threads provides adequate lead and assists in clearing the chips. Such taps are satisfactory for through holes and for blind holes when they are followed by a bottoming tap. Small pipe or tapered holes need not be taper-reamed, even though this is usually necessary for large holes.

A lubricant such as white lead or oil mixed with heavy grease or paraffin wax may be used for hand tapping. High speed work requires lubricants of lower viscosity, such as mixtures of lard and paraffin oils or any one of several screw-cutting compounds commercially available. Smooth and accurately cut threads do not seize; if seizing is a problem, thread lubricants may be used, such as zinc stearate or compounds of graphite and oil or grease.

Drilled holes which are to be tapped should not be too small otherwise the per cent of full thread which must be formed may be excessive. This point requires attention in deep holes where the tap engagement is long; even for short tapped sections the per cent of full thread should not exceed 75.

Thread chasers for aluminum alloys should be chamfered for one or more threads and provided with a top rake of 25 to 45° in addition to a side rake of 8 to 10°. Available dies differ, among other things, in the method and accuracy of adjustment. Certain dies are capable of fine adjustment, are easily resharpened, can be run at high speeds, and provide adequate room for penetration of lubricant and clearance of chips.

Dies of this type are particularly good for threading aluminum forgings and castings.

Excellent threads may be chased in all aluminum alloys on an engine lathe with a single pointed threading tool having the proper top and side rake and ground to the required thread contour.

Reaming — Solid, expansion, or adjustable reamers are used in aluminum alloy forgings and castings. Flutes may be straight or spiral although the latter frequently produce better results. A reamer having a spiral in the direction of tool rotation cuts free but "hogs in"; therefore reamers are often used with spirals *opposed* to the direction of rotation. This type cuts slower but is under better control. Special reamers are available with alternate spirals, one of which cuts freely, while the tendency to "hog in" is retarded by the opposing spiral; furthermore, they produce holes free from chatter.

A good carbon steel reamer is used where very accurate holes are required but for production jobs high speed steel tools produce acceptable results over a longer period of time. The edges should be honed sharp at all times and under these conditions speeds of 65 to 200 ft. per min. and feeds of 0.010 to 0.030 in. per revolution may be used. Sufficient finish should be allowed so the reamer cuts rather than scrapes.

Lubricants described under tapping are applicable, depending on whether the job is run at low or high speeds. For the latter, a cutting compound which is also a coolant will maintain the work at low temperature and minimize distortion. Distortion also may be reduced by carefully clamping the casting or forging.

When conditions will permit, holes of greater smoothness, roundness and straightness can be produced by boring rather than reaming.

Sawing — Saw life is a maximum when cutting Type I non-heat-treated casting alloys and Type III wrought alloys, although the latter tend to load and require a more generous use of the cutting compound. The life of the saw is somewhat reduced when cutting heat treated castings and forgings; when possible, these should be sawed before heat treatment. Alloys A132 and 32S are hardest to cut regardless of thermal condition. Thick sections also seriously reduce band saw life; consequently circular or power hack saws are recommended.

Heavy duty band saws made of spring temper steel are widely used for aluminum forgings and castings because of the ease with which the blades can be sharpened and reset. These saws should have coarse teeth with large curved gullets for chip room. When the work is fed by hand the teeth should have very little top rake; otherwise they will enter the work too rapidly. Where the feed is mechanical and the work securely clamped to the table the teeth may have a side rake of 10 to 15° and a 5° top rake or hook.

Certain types of work are cut very satisfactorily with band saws or power hack saws using blades of the hard tooth, flexible back type with no provision for resharpening or resetting throughout the life of the blade. Such saws with coarse teeth, eight points or less to the inch, and of the wavy set type are preferred.

The use of a circular saw is indicated where a smooth finish is required, or where the alloy to be cut is hard, or where the stock is of heavy cross section. Furthermore, heavy sections can be cut more accurately with circular saws. The inserted tooth, high speed steel, circular saw performs better than one of carbon steel although its initial cost and maintenance are higher. Preferable to either of these is the saw tipped with cemented carbide, which may have a hook of 5 to 10° and circum-

Data on the Sawing of Aluminum Alloys

	Band Saw	Circular Saw	
		Solid	Inserted Carbide Teeth
Size	16 to 24 ft.	14 in.; medium	24 in.; large
Thickness	18 to 19 gage		
Width	1¼ in.		
Kerf	0.075 to 0.095 in.	⅛ in.	¼ in.
Teeth	4 point 3	30	50
Set	Alternate	None	None
Peripheral speed			
Thin	8,000 ft. per min.		
Diversified	4,000 ft. per min.	6,500 ft. per min.	11,000 ft. per min.
Heavy	3,000 ft. per min.		
Feed			
Heat treated alloys *(a)*	Hand	4 to 17 in. per min.	4 to 17 in. per min.
Other alloys	Hand	17 to 24 in. per min.	17 to 24 in. per min.
Lubricant	Grease stick	Soluble oil (20:1) with kerosene or lard oil	

Note: *(a)* Also 32S and A132, regardless of temper

ferential clearance of 8 to 10°. Beyond this point the inserted tooth may be cut away at some convenient angle such as 28 to 40° to form a generously shaped gullet. Heavy feeds are used, hence adequate chip room must be provided, which means that the spacing of teeth must be coarse. At high speeds and feeds a sturdy machine designed to operate under these conditions is necessary to eliminate vibration. A continuous flow of a lubricant, which may be soluble oil containing a small amount of kerosene or lard oil, is desirable. Additional data are contained in the table at the bottom of the preceding page.

Rough Grinding, Polishing, Buffing — The free-cutting aluminum alloys of all groups cause no trouble during grinding, polishing or buffing. Those which are gummy clog the wheels; hence the grease stick should be used more generously. The harder and denser the alloy the better is the color developed.

A balance should be struck between the life of the wheel and the speed of cutting — that is, a hard wheel lasts longer but cuts slower. To maintain cutting efficiency the speed of the wheel should be increased as it wears away. The table above contains detailed information on all grinding operations.

Finish Grinding — The importance of maintaining accurate control over dimensions differentiates between the techniques of rough and finish grinding. The heat treated casting or forging alloys should be ground cautiously since their greater resistance to cutting generates heat which, in turn, renders maintenance of dimensions difficult. The harder alloys, however, have brighter surfaces.

A wheel must be dressed with care preferably at low speed and with a single pointed diamond. The cutting compound should be of low viscosity as its primary function is that of a coolant. If too viscous, abrasive particles or swarf will not settle during recirculation and these will mar the work.

Filing and Sanding — Files with single-cut, coarse teeth which have ample top and side rake work best on aluminum alloys. A long-angle lathe file is excellent for finishing. These are very satisfactory for lathe or flat work but the nature of some jobs indicates the need for a square, three-cornered, half-round, or round file and in such cases bastard cut files of standard shapes find wide use. These will clog but they are available at low cost.

In many instances files of standard shape can't be used and in such cases coarse tooth rifflers, spiral cut rotary files or burrs, end brushes, small polishing wheels, or sanding drums of different sizes with sleeves of various grits are used.

Grinding, Polishing, and Buffing Aluminum Alloys

	Grinding			Polishing		Buffing	
	Rough	Belt	Finish	Rough	Finish	Cutting Down	Coloring
Abrasive	SiC	Al_2O_3	SiC	Al_2O_3	Turkish emery	Tripoli	Lime compound
Carrier	Solid wheel	Cloth belt	Solid wheel	Sewed muslin buffs, glued		Pocketed muslin buff	Loose buff, high count
Grit	24 if machined 40 if buffed	46 to 300	30 to 40	46 to 120	150 to 240		
Bond	Bakelite	Glue	Vitrified	Glue	Glue		
Hardness	Medium		Soft	Medium	Medium		
Peripheral speed of wheel, ft. per min.	6,000 to 9,000	<3,000	6,000 to 7,000*	6,000	6,000	3,000 to 7,500	3,000 to 7,500
Lubricant	Grease	Grease or kerosene	Soluble oil 35 or 40 to 1	Grease	Grease		

*Peripheral speed of work 150 ft. per min., feed on 2 in. wheel, ½ in. per revolution of work.

Closure

A machinist, supplementing his own background with the information contained in these two articles, should be able to machine aluminum forgings and castings successfully within the limits imposed by the particular alloy. His experience will suffice where tools of standard design and practices in common use prove satisfactory, whereas the foregoing discussion will serve as a guide where tools of special design or modified operating conditions are indicated to insure better results.

Correspondence

bakelite or lucite (as mentioned in the above-noted article in METAL PROGRESS), or of allowing the electrolyte to come into contact with any organic material cannot be too strongly emphasized.

In addition we wish to point out the danger of attempting to use electrolytes containing perchloric acid to polish bismuth or bismuth alloys. In a rapid search through the literature on electrolytic polishing we have noticed no reference to this last mentioned hazard.

The purpose of this letter is not so much to discourage the use of electrolytes containing perchloric acid, but to prevent gravely serious accidents that may occur through ignorance of the dangers which accompany careless handling of the solutions.

M. E. MERCHANT
Basic Science Research Laboratory
University of Cincinnati

Warning!
Perchloric Reagents May Explode

CINCINNATI, *Ohio* — In the article "Electrolytic Preparation of Iron and Steel Microspecimens" (METAL PROGRESS for January, 1940) no explicit mention is made of the possible explosion hazards involved in the use of electrolytic polishing solutions prepared with perchloric acid and acetic anhydride or acetic acid. In fact, this neglect seems to be quite general in much of the literature concerning these methods and their electrolytes.

Mixtures of perchloric acid with any organic material are well known as potential explosives, especially when heated, and the explosions are usually extremely violent. There is no general agreement as to the conditions for such explosions and their causes. The behavior seems to be rather erratic and unpredictable. Furthermore, hot perchloric acid forms a very explosive product with bismuth or bismuth alloys.

These facts are obviously pertinent to the use of the above-mentioned polishing electrolytes, and indicate that protective measures should be taken when such solutions are employed, *particularly at the time of mixing.* JACQUET and ROCQUET's injunction in *Comptes Rendus*, page 1012 (1919) to chill the ingredients before mixing should receive emphasis, for a large amount of heat is evolved when compounding mixtures of perchloric acid and acetic anhydride. The danger of using specimens mounted in organic substances such as

Die Manufacture and Stretching Press for Aircraft Sheathing

BALTIMORE, *Md.* — Two items of metallurgical interest have recently been developed by the Glenn L. Martin Co. in connection with the forming of curved sheets for cowling and other parts of aircraft fuselage, and dies therefor. One is a patented furnace for melting zinc and zinc alloys for making drop hammer dies. Ordinarily the zinc is melted in a cast steel or iron pot, heated externally in a fire-brick setting. Even when carefully designed to distribute the heat over the pot, it is very difficult to avoid hot spots. The principal difficulty with this is that the iron at these points alloys with the soft metal within, not only contaminating the zinc alloy but endangering the steel or iron container.

The new furnace was designed by the undersigned in conjunction with HUGH E. BURKE and CHRISTOPHER J. FREY of the research staff. Instead of applying the heat directly, the pot containing the zinc to be melted is suspended in a mass of molten lead or other metallic alloy having a lower melting point than the zinc, which transfers heat to the pot containing the

zinc. This provides for an even distribution of the heat to all parts of the pot, eliminates the points of heat concentration, and has ended pot erosion.

The furnace therefore consists essentially of two pots, the larger of which completely surrounds the bottom and sides of the smaller, with space arranged between the two for the introduction of an adequate amount of the lead mass through which the heat is transferred to the inner pot. Underneath the larger or outer pot is a combustion chamber. Flues have been provided which communicate with the bottom of the combustion chamber and which extend upward along the outside of the furnace. The outer pot is supported by angle members which rest on the base plate beneath the bottom wall of the casing, and are covered with refractory material to prevent corrosion of the metal supports.

Furnaces for Melting Zinc (for Dies for Forming Duralumin Sheet) Wherein the Zinc Container Is Immersed in a Lead Bath for Quick and Uniform Heating. Typical die molds are shown at left, foreground

In other words, the inner pot, which contains the more reactive zinc, is operated without the development of hot spots. Localized areas of elevated temperature by this method are limited to the outer iron pot containing lead, in which difficulties due to alloying of iron and lead are not experienced.

The accompanying view shows our battery of furnaces in the die foundry. The operator is placing one of the zinc containers in the center furnace. (Another container is at the extreme right.) The furnace at the left has its cover lowered, to conserve heat. Note the hinged hoods, which when lowered in place completely enclose the furnace tops.

The second item is also illustrated. It takes the form of a metal stretching press, thought to be unique, and built by the Engineering and Research Corp. of Riverdale, Md., to Martin specifications.

Primarily, the machine consists of two hydraulic cylinders placed beneath a platen between two rows of independent clamp jaws. The cylinders are attached to the platen in such a manner that they raise or lower the platen vertically. These cylinders operate in tandem, making it possible to obtain an angular position of the platen if desired.

In operating the press a form is placed on the platen. The sheet of duralumin to be stretched is placed over the form and clamped tightly in the rows of jaws at either side. Pressure is now applied on the hydraulic cylinders, causing the platen to move up — stretching the sheet tightly over the form.

When the sheet has been sufficiently stretched so that it hugs the die tightly, the pressure is released and the formed piece also released from the block. It is interesting to note that in the stretching process the thickness of the material is reduced only from 5 to 7%.

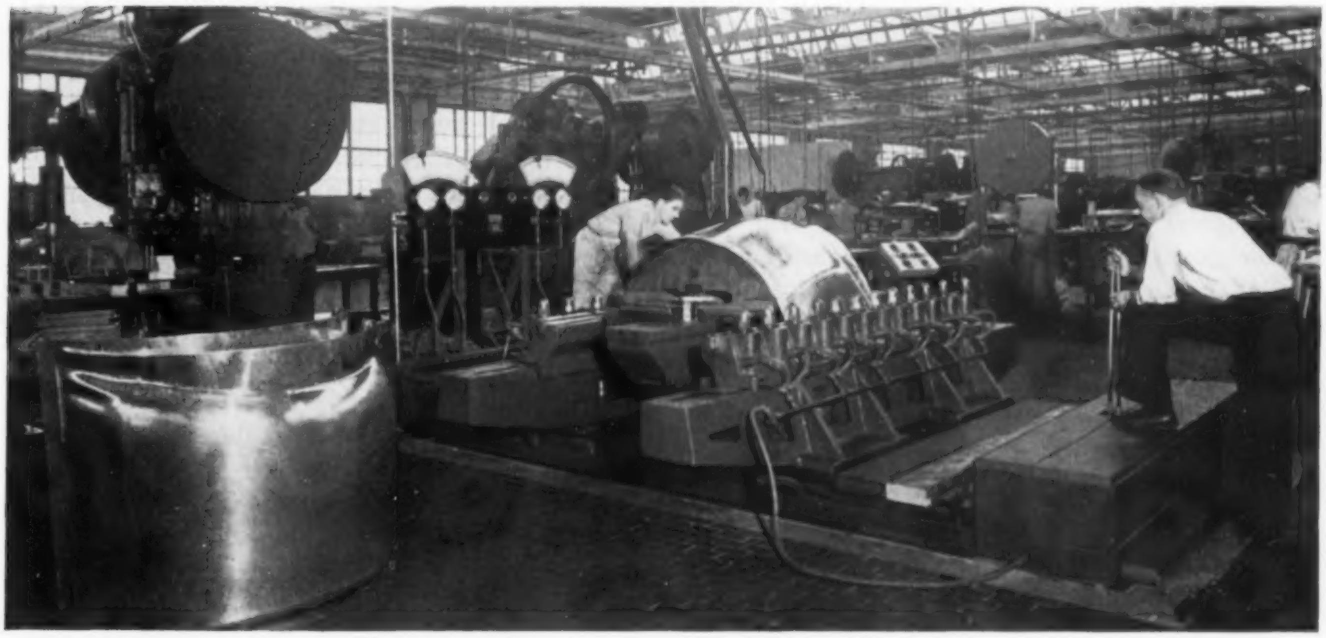
The entire operation takes but a few minutes; therefore, it will be readily seen that much time is saved over the former method of bumping in a power hammer or forming under a drop hammer. Forming by the stretching process seems to be the happy medium between these slower operations and high production methods used in the automotive industry and requiring expensive forming dies and very powerful presses.

Form blocks used on the press are of wood

construction covered with a sheet of 0.040-in. deep-drawing body steel. The form blocks are made to the exact contour required, since there is little or no spring back to contend with in duralumin.

The stretching press is used principally for the forming of large sheets, such as skins and engine cowlings which were formerly shaped on a power hammer. It fills a definite need, principally through absorbing work which required the use of hand tools, and enables us to turn out work on a production basis. It does not in any way take the place of the drop hammer, but it appears probable that some parts that are now formed on the drop hammer may in the future be successfully manufactured on the new stretching press.

Reid B. Gray
Chief of Laboratories
The Glenn L. Martin Co.



Stretching Press at Glenn L. Martin Aircraft Plant. Large duralumin sheet, held at two opposing edges by clamping jaws, is molded by upthrust of form on central platen

Criterion for an A-1 Gray Iron

DARLASTON, *England* — In the final sentence of the note entitled "Criterion for an A-1 Gray Iron" which appeared on page 162 of Metal Progress for February, the Editor makes an observation regarding the impact strength of gray iron in the heat treated condition. This sentence follows: "If good toughness and high strength are *both* desired, get it in a pearlitic or alloy iron *without* heat treatment, because quenched and tempered castings never have the impact strength they have as-cast." If it is intended to infer that heat treatment of gray iron by hardening and tempering is inevitably accompanied by an increase in brittleness when compared with the as-cast condition, then I take the view that this statement is misleading.

In my own work on this subject I endeavored to study the character of the stress-deflection curves. Typical results are to be found in several papers of mine on this subject, in particular the one on "The Influence of Phosphorus on Hardened and Tempered Cast Iron" in the *Journal* of the Iron & Steel Institute, Vol. I, 1933. With the material with which I worked, which was centrifugally cast, I formed the opinion that hardening and tempering was accompanied by *increased* toughness as compared with the as-cast material, and that this increase was of a substantial order in the material which had the lower phosphorus contents.

In the discussion on this paper T. R. Twigger, another worker in this field, stated that he had "endeavored to obtain a measure of the toughness (as compared with brittleness) of hardened and tempered cast iron by some direct impact tests which approximated both to single blow impact and to repeated impact on the lines of the Stanton test, and it had been clearly shown that when the tempering was carried out at temperatures (normally 575 to

650° F.) which gave maximum strength properties, then the impact value was at least as great as in the as-cast condition; in fact in the repeated impact tests it was conclusively shown that the resistance to fracture of hardened and tempered samples was many times that of the as-cast material."

J. E. Hurst
Darlaston Blast Furnaces
Bradley & Foster, Ltd.

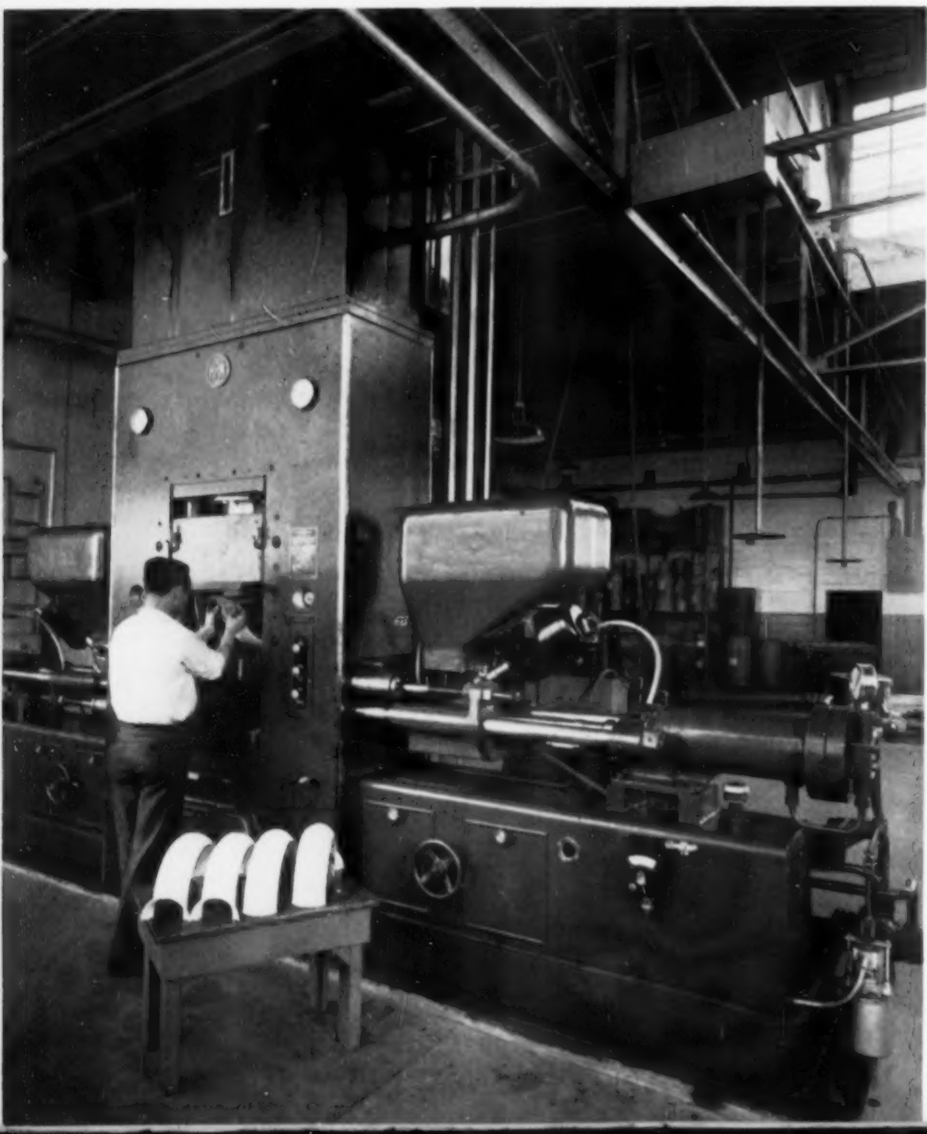
Important Developments in Electrical Cable

New York — An article by Carleton Cleveland appeared in the January 1940 issue of Metal Progress entitled "Important Developments in Electrical Cable". On page 59 this statement is made: "Research and experimentation still continued. By reducing the wire two more numbers . . . . today 2121 pairs of wire are squeezed into the same sheath." The statement "by reducing the wire two more numbers" is quite incorrect. There has been no reduction in wire gage in the 2121-pair cable as compared with the older 1818-pair measurement. Both are made up of 26-gage wires.

In the interests of accuracy and the record, I imagine you may wish to correct this erroneous statement in some subsequent issue of your publication.

William A. Wolff
Information Manager
Western Electric Co.

Duplex, Vertical Type of Injection Molding Press Built by Hydraulic Press Mfg. Co., Photographed in Plastic Division, Metal Specialty Co., Richmond, Ind., Making Lamp Housings Weighing 9 Oz. Each. The machine is really two independent units, right and left hand, individually operated. Feed mechanisms transfer granular material from hopper into jacketed injection chamber where it is heated, and then pressed into the mold at 20,000 psi. Directly applied hydraulic power is used for every pressure action. Speed is 3 to 5 cycles per min.



Unlikely That Creep Tests Are Influenced by Tremors

Chicago, *Ill.* — The letter published in the April issue of Metal Progress from Mr. Babcock pertaining to "Irregularities in Creep Tests Possibly Due to Tremors" bears on a matter which has been given very careful consideration by creep investigators almost since the time such investigations became of industrial importance. It has been found that ordinary tremors in creep apparatus are not in any way responsible for most of the sharp deviations noted in creep curves. Such abrupt changes in directions of the curves may be due to a number of causes, depending upon both the material under consideration and the methods of tests. Investigations of such deviations for steels have shown, in general, that they frequently arise due to discrepancies in temperature control. It is well known that relatively small variations in the average test temperature produce marked changes in creep rates. In cooperative tests, where one laboratory has obtained jagged curves on a given material, another has produced smooth curves merely through more careful temperature control.

It is true, however, that violent vibrations in the testing apparatus might produce seismic influences and consequently most careful investigators have taken precautions to avoid such effect, either by placing machines in locations free from vibrations, or by using flexible mountings, or by using dash pots to damp vibrations due to dead loading arrangements. Systematic investigations of the effect of mild "seismic" vibrations have not shown any

marked differences. Investigators in one creep laboratory have used a buzzer to produce vibrations in the apparatus to keep the creep "up to date", as they aptly expressed it. The writer and others have studied the effect produced in dead load tests due to 60-cycle vibrations arising from the inductive effect upon the test bars and holders. Check tests conducted in non-inductively wound furnaces, and even made by substituting direct current for alternating, have failed to find any conclusively different character or rates of deformation in the creep curves.

Mr. Babcock does not make clear what materials are represented by the creep data to which he refers. Some investigators of coarse-grained lead have found irregularities which occurred even though extraordinary precautions had been taken to avoid "seismic influence". Varied explanations of the mechanism of creep in coarse-grained metals, which have been given previously in the literature, recognize the possibility that such jagged curves might originate in coarse-grained materials through accumulations of strain on a microscopic basis resulting in sudden periods of slip which might be likened to earthquake effects.

J. J. Kanter
Research Metallurgist
Crane Co.

Toughness (Impact Strength) Unaffected by Alternating Stresses (Fatigue)

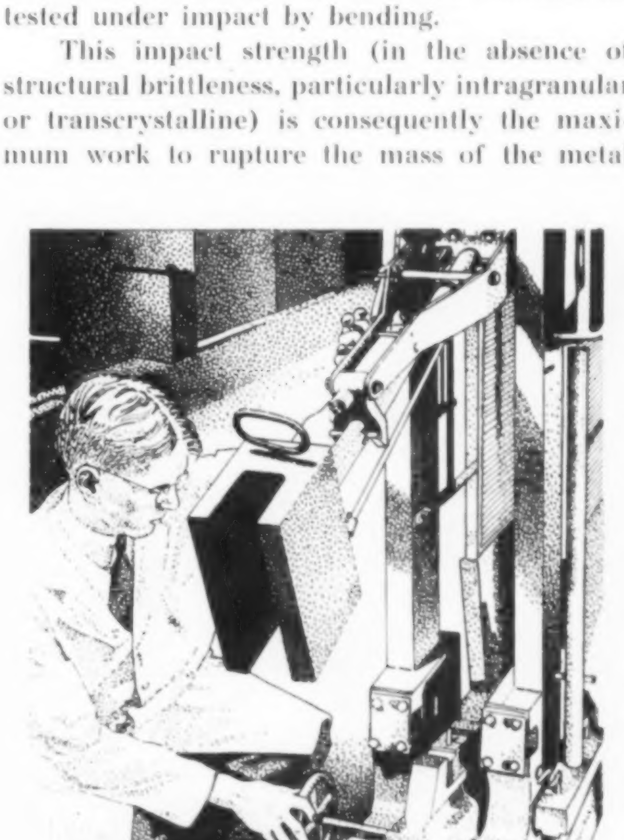
PARIS, *France* — Among the various types of rupture in service of a metallic part, two particularly important types can be distinguished one from the other by their mechanism, their appearance and their relationship to other standard tests. They are fatigue failures, and brittle fractures.

Fatigue, or rupture on alternating stress by progressive and sometimes slow propagation of a crack in the metal, has a dull, smooth fracture. (This should not be confused with corrosion cracking under continuous stress, where there is likewise intercrystalline or intergranular propagation of the crack, which often branches out and shows a granulated fracture with an oxidized or chemically altered surface.) Resistance to fatigue failure is known as endurance, and is denoted by the fatigue or endurance limit F determined in pounds per square inch by means of cyclic tests, generally alternating from a certain tension stress to an equal compression stress by rotating the test piece while loaded in bending.

This fatigue limit F varies in the same way as the ultimate tensile strength T and the yield point Y. Attempts have therefore been made to connect F (which requires long and expensive tests for its determination) with these two values T and Y. However, in order to express such a relationship, it is necessary to introduce certain coefficients of deformation — either the reduction of area R, or the impact resistance I. (Thus the writer has endeavored to connect F with the breaking stress on the reduced section $100\ T \div (100-R)$ and M. Pomey has given some empirical formulas involving the tensile strength T and the impact strength I.)

The second type of rupture mentioned at the outset is a structural or crystalline brittleness caused by sudden breaking of the part under impact. Such broken pieces have a granular fracture, dull if the rupture is intergranular or with bright facets if rupture is transcrystalline by cleavage. The resistance to this type of rupture is the impact strength I in foot-pounds, and is determined by the work required to break notched bars of standard dimensions tested under impact by bending.

This impact strength (in the absence of structural brittleness, particularly intragranular or transcrystalline) is consequently the maximum work to rupture the mass of the metal

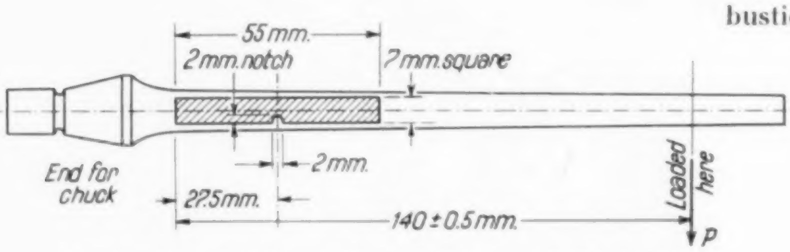


deformed before breaking. It can thus be related to the area under the stress-strain curve of the metal, which depends not only on the tensile strength, but also chiefly on the plastic deformation expressed by the reduction of area *R*. When rupture is intragranular or transcrystalline, by cleavage of the grains, there is little or no deformation before rupture and a quantity is obtained that is entirely different from the figures for static rupture and cannot be related to them. Such is the case, for instance, with as-cast steels superheated or embrittled by tempering.

It is in interpreting these particular types of rupture and characterizing their effects, that the impact test acquires its particular significance, completely different from other characteristics and mechanical tests. In other tests there is generally some relationship or analogy taking its origin in common factors that may be expressed by direct or indirect mathematical relationships.

However, another kind of relationship has been sought between fatigue and impact strength, on the assumption that the alternating stress or vibration occurring during the fatigue test could develop brittleness by "crystallization of the metal", involving a decrease in impact strength.

Many a time, in fact, "grain growth caused by fatigue" has been used to explain the service failure of parts showing a coarsely crystalline fracture and low impact strength. These conclusions, however, are drawn *after* failure, and it is not known whether the piece did not already show these characteristics before being placed in service, as often happens because of poorly planned or poorly executed heat treatment. In other words, when only the final condition and not the initial condition is known, no conclusion should be drawn. It would indeed be advisable to submit this interpretation to experiment, finding out whether it is possible to cause an increase in brittleness and grain growth by means of fatigue (alternate stresses). If embrittlement during fatigue is more than wishful thinking, the phenomena must be evident on fatigue test specimens as well as on parts in service.



Impact Test Pieces Were Cut From Fatigue Test Pieces (Cantilever Type) but no Evidence of Embrittlement by Alternating Stress Could be Found

Impact test specimens may be cut from fatigue test specimens in regions where the stress conditions are known exactly, and it is then possible to determine the impact strength as a function of the fatigue. Thus a convenient experimental method is provided which no one apparently has tried.

Some experiments have been undertaken by M. de Lacombe, which use fatigue test pieces of the type adopted by the French aeronautic department and shown in the accompanying figure. The distribution of stresses is exactly known and there is sufficient length beyond the neck of the housing where the stress is approximately constant. If rupture does not occur in the center of the zone, which frequently happens, there remains enough metal, as indicated on the figure, to take an impact specimen of 7x7-mm. section (Mesnager notch of 1 mm. radius and 2 mm. depth). Thus, it is possible to compare the impact strength of the unstressed metal with that obtained on test pieces submitted to a variable number of alternations, with or without breaking.

Following are some results so far obtained on alloy steels of the type 0.25 to 0.30% C, 4% Ni, 1.5% Cr, 0.5% Mo, so often used for combustion engine crankshafts.

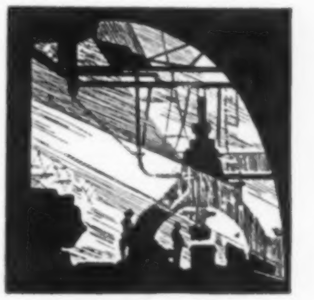
Number of Alternations Endured	Stress in Section at Notch; Kg. per Sq.Mm.	Impact Strength; Kg-M. per Sq.Mm.
0	0	10.0
2,620,000	54.6	11.2
16,766,000	52.5	10.0
621,000	50.8	11.2
1,508,000	50.8	11.2
12,500,000	50.8	11.2
159,000	50.3	11.7
11,300,000	50.3	11.7

It can be seen that the results obtained differ no more than can be attributed to experimental error (if they differ at all). While the results are negative insofar as any indication of embrittlement by alternating stress is concerned, these determinations should be continued on various steels treated in various ways before a general statement could be made.

Albert M. Portevin
Professor
Ecole Central des Arts et Manufactures

Forging
As it Is in 1940

CHICAGO HEIGHTS, *Ill.* — Unfortunately three words were left out of my manuscript for the Anniversary issue of METAL PROGRESS (page 315, March 1940). The fourth paragraph should have read as follows, by the insertion of the four missing words now printed in italics:



"Large mechanical presses are making various types of forgings. *In steam forging hammers,* after a period of interest in and trial of equipment of extraordinary size without too satisfactory results, orders are now commonly being placed with a rating up to 22,000 lb."

This error of omission reflects upon the manufacturers of large forging presses and the statement should be corrected.

ADAM M. STEEVER
Superintendent
Columbia Tool Steel Co.

Tensile Testing of Steels With Duplex Microstructure

KREFELD, *Germany* — Variations in speed of the testing machine, within usual limits, have little or no effect on the results of the tension test on plain carbon and alloy steels. The exception to this statement was noted by LAWFORD H. FRY in an article in METAL PROGRESS last January, in which he assembled data showing that yield point increases slightly as the rate of strain increases. However, the tensile strength and elongation are also affected by the rate of strain when the material tested is an austenitic steel, and the closer the austenitic steels lie to the transition range between austenitic and martensitic steels, the greater is the influence of the rate of loading.

In this connection it should be of interest to observe the behavior of austenitic chromium-manganese steels containing various proportions of ferrite. Steels were selected for these investigations of the following compositions:

STEEL	C	MN	CR	NI	STRUCTURE
1	0.15	16.0	9.80	0.70	Pure Austenite
2	0.12	9.0	16.0	1.60	10% Ferrite
3	0.12	9.8	16.8	1.30	30% Ferrite
4	0.11	9.2	18.0	1.20	50% Ferrite

These steels were all quenched in water from 2100° F. and the percentage of ferrite determined by micro examination. Five samples of each steel were tested, the rate of strain being 5, 10, 25, 50 and 90 mm. per min. (The normal rate of loading would be about 25 mm.)

The following observations might be made for the austenitic steel No. 1: The yield strength remains at about 42,500 psi. up to testing speed of 25 mm. per min. but then rises sharply to 65,000 psi. at 90 mm. per min. Tensile strength at slow speed is 140,000 psi., decreasing only slightly with higher speeds. Elongation on 5 diameters, when tested at 5 mm. per min., is 53% and drops to 43% when strained at 90 mm. per min.; the reduction of area correspondingly increases (47% to 63%).

The behavior of this austenitic manganese-chromium steel is in contrast to that of an austenitic manganese steel with 1% C and 13% Cr. According to investigations by MUSATTI and HEUGONI its tensile strength and yield strength both increased with increased rate of loading, and furthermore both the elongation and reduction of area attained higher values.

The values for chromium-manganese steel No. 2 with 10% ferrite are as follows: Yield strength increased in the same range as noted above for the wholly austenitic steel, the figures being 40,000 psi. and 50,000 psi. respectively. Little significant change was found in the ultimate strength: 150,000 psi. *Both* the elongation and the reduction of area increased with more rapid testings, the figures being respectively 37 and 36% at 5 mm. per min., and 46 and 48% at 90 mm. per min.

As a result of the 30% ferrite in Steel No. 3, it has a higher yield strength (56,000 psi. at slowest rate of testing) and this increases only slightly (to 62,000 psi. at most rapid testing). We also note a significant drop in tensile strength (135,000 and 118,000 psi. at the two limits). Elongation increased very slowly, from 41% to 45%, but the reduction of area steadily and largely increased, being 38% at 5 mm. per min. and 55% when stretched at 90 mm. per min.

In Steel No. 4, which is half ferrite and half austenite, the yield strength is quite high (60,000 psi.) and is unaffected except at the highest rate of loading. Conversely the ultimate strength is low, 105,000 psi., and decreases slightly with speed of loading. Elongation and reduction of area (48% and 55%) increase only slightly. Evi-

Influence of Ferrite on Tensile Properties

Steel	No. 2	No. 3	No. 4
Ferrite content	10%	30%	50%
Yield strength, psi.	40,000	60,000	60,000
Ultimate, psi.	155,000	125,000	110,000
Elongation in 5 dia.	41%	42%	50%
Reduction of area	43%	46%	59%

dently this steel tests more like a pearlitic carbon steel than like an austenitic alloy steel.

Finally, some information on the specific influence of ferrite on an austenitic steel may be deduced from a study of the data for steels No. 2, 3, and 4 (not very different in chemical composition) when tested at 25 mm. per min., the normal rate of crosshead speed. These figures are contained in the table above from which can be drawn the following conclusions:

The yield strength increases rapidly up to a ferrite content of 30% and then remains constant. The tensile strength decreases very considerably with increasing ferrite content. The elongation and reduction of area increase with increasing ferrite content.

These figures make it obvious that, when testing the light alloy steels, the speed of the testing machine must be standardized. Likewise, surprising variations in results may be expected in steels of duplex microstructure (that is, part gamma and part alpha iron).

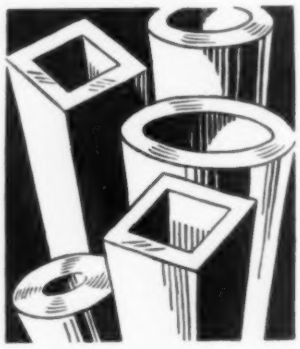
H. Hougardy
Research Laboratories
Deutsche Edelstahlwerke A.G.

Centrifugal Casting for Quality

TURIN, *Italy* — The application of the centrifugal casting processes has so far been limited in Europe principally to the production of ordinary cast iron pipe. I believe that the first industrial application of this process was made in the United States about 1912 or 1913, using patents of the Brazilian engineer Dimitri Sensaud de Lavaud. Two kinds of molds are now used by competing companies, *(a)* a permanent mold and *(b)* a sand mold.

After the War, the same principles were applied in Great Britain, with special new machinery, for the production of cast iron cylinders of high quality, especially for piston rings and liners for all sorts of internal combustion engines. This special machinery has been greatly improved during the last few years, and among the important recent innovations different ingenious water cooling devices for the revolving molds may be quoted, increasing their durability, facilitating the extraction of the cast piece, and improving the quality of the castings.

More recently, similar centrifugal casting processes have been successfully adapted to the production of tubular or annular castings of non-ferrous alloys, especially bronzes and brasses, and of considerable size. These are used for paper mill rolls, rolls for textile machinery, sleeves to protect propeller shafting from salt water corrosion, copper driving bands for shells, and all manner of hubs and short cylinders. Tubes of high chromium, heat resisting steel are also being successfully cast, as described by R. J. Wilcox in Metal Progress for January 1936.



Considerable publicity was given some time since to the centrifugal casting of gun tubes for field and naval artillery in American arsenals, these alloy steel tubes later to be expanded by auto-frettage and perfected by heat treatment. Projectiles have a shape, both interior and exterior, that lends itself to the process.

Likewise there is no need to remind Americans of the many important uses made of the process by their automotive industry, ranging from "spinning-in" babbitt into connecting rod bearings, "centrifusing" of cast iron brake linings into pressed steel shells, and the manufacture of alloy steel blanks for transmission gears.

In all cases the advantages of the process can be divided in two groups, the first concerning the facility and the economy in the production of castings of special forms, and the second concerning the advantages connected with the higher quality of the cast metal.

Extensive experience obtained during the last few years in this field shows that the advantages of the second group are by far the more important. In fact, all other conditions being the same, centrifugal cast pieces show superior physical properties (and especially wear resistance), better uniformity of composition and structure, and less porosity. *(Cont. on page 568)*

Centrifugal Casting

(Continued from page 566)

Under these circumstances it seems peculiar that the advantages of the second group have so far been utilized in Europe only when centrifugal casting is utilized for its economy. In other words, it seems remarkable that the excellent properties of metals and alloys obtained by centrifugal casting have not yet been extensively exploited for the manufacture of a great number of pieces of various forms and types, not limited to the tubular or annular forms directly shaped by the rotating mold. This fact seems the more remarkable as, on several occasions during the last 20 years, high quality castings in shapes other than tubular or annular have been experimentally produced.

In addition to the rather scarce information to be found on this subject in the technical literature, I had the opportunity of following very closely the extensive and successful experiments made about 15 years ago by the late Elisée de Loisy, the great French metallurgist, for obtaining high quality steel ingots and castings by a centrifugal casting process.

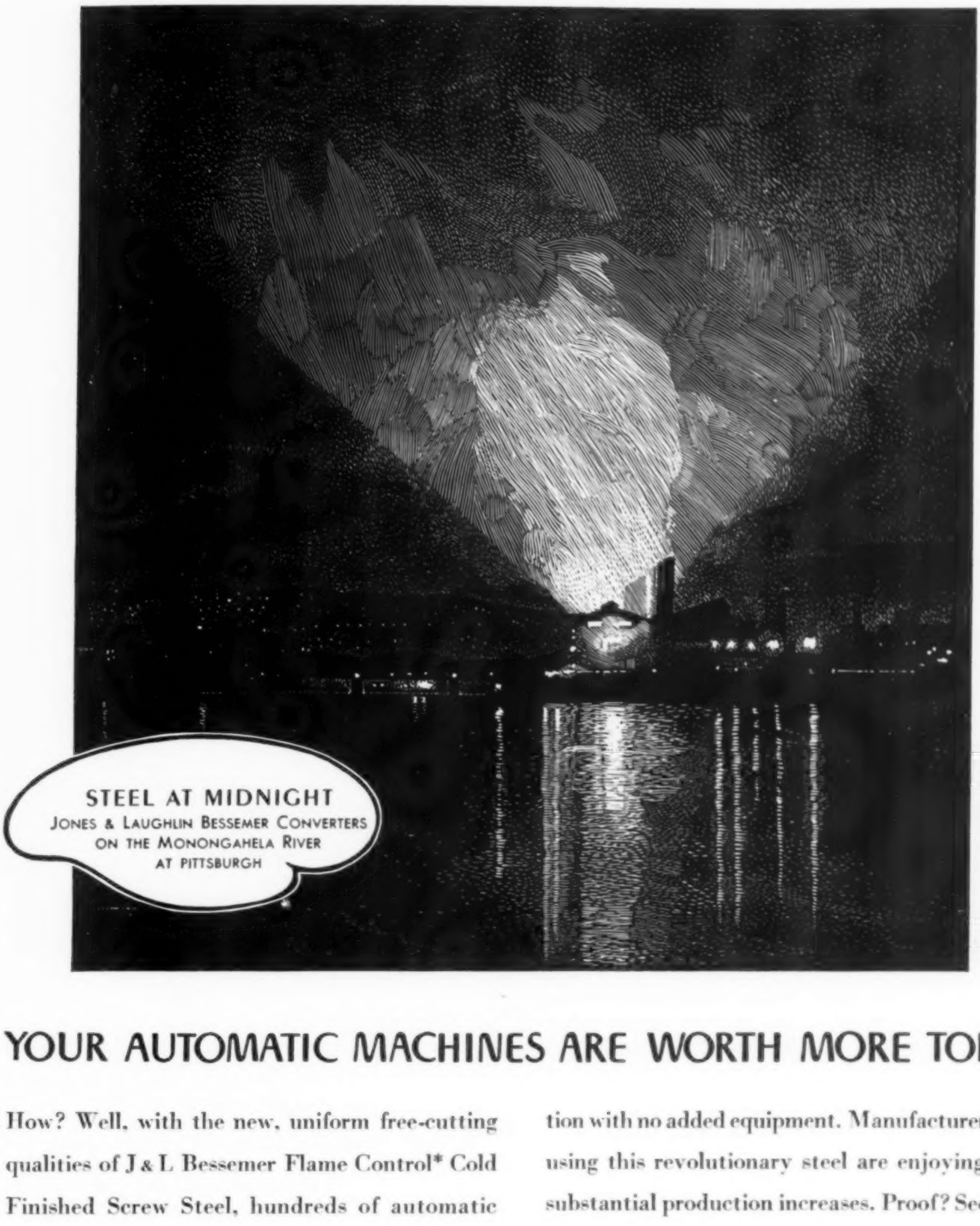
These experiments (unfortunately interrupted by his death in 1929) were made on a large industrial scale, and gave such remarkable results — both as to quality of the metal and uniformity and compactness of the ingots — that it would certainly be very interesting to resume and complete them.

de Loisy's first object being that of obtaining sound, flat ingots to be rolled into thin sheets, he used rotating vertical molds whose internal surface was divided by vertical diaphragms, extending inward about one third of the radius. In other cases, molds of different forms were arranged on the internal surface of the rotating cylinder in order to obtain ingots and castings of special types. In all cases, losses from crop ends were reduced practically to zero.

These interesting experiments have not been resumed. Similar and extensive work, I believe, was done at Detroit, Mich., between 1930 and 1935 by Rotary Electric Steel Co. Since this company now utilizes the conventional steel making methods, it can be surmised that the experiments were not entirely successful, as far as conditions existing there are concerned. It would be most interesting if these results could be published.

In some cases I have been able, in the solution of special casting problems, to apply the principles of the de Loisy process, and nearly always with complete success.

Federico Giolitti
Consulting Engineer



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J&L STEEL

Personals

A. Oram Fulton, Jr., salesman for Wheelock, Lovejoy & Co., has been transferred from the Buffalo office to the main office at Cambridge, Mass.

Robert A. Peterson has been appointed superintendent of hot mills, Cuyahoga Works, American Steel & Wire Co.

W. Paul Gerhart, formerly assistant metallurgist, Maryland plant of Bethlehem Steel Co., is now assistant metallurgical engineer in the central metallurgical department at Bethlehem, Pa.

Eugene P. Larson has transferred from the fluorescent materials laboratory of Hygrade Sylvania Corp., to assistant metallurgist at Emporium, Pa., under Chief Metallurgist Walter E. Kingston.

Transferred by The Linde Air Products Co.: J. A. Rea, formerly service engineer in the Chicago district sales office, to a similar position in the Cleveland office.

George V. Harris, formerly metallurgical engineer with Lindberg Steel Treating Co., Chicago, is now metallurgist for Belle City Malleable and Racine Steel Castings Co., Racine, Wis.

Raymond R. Schaefer, has resigned from the development and research division of the International Nickel Co. and joined the metallurgical department of the American Brake Shoe and Foundry Co., and is located at Mahwah, N. J.

D. E. Wyman, formerly chief engineer of the industrial furnace division of the Philadelphia Drying Machinery Co., is the new vice-president and chief engineer of R-S Products Corp., Philadelphia. W. E. Borbonus has replaced F. J. Ryan as president.

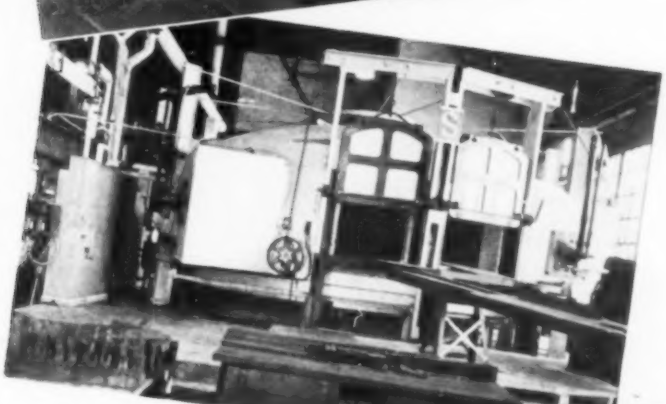
F. L. LaQue, assistant director of technical service on mill products, development and research division of the International Nickel Co., is now engaged in development activities on all applications of both ferrous and non-ferrous nickel-containing alloys. William A. Mudge, recently transferred to the development and research division from the rolling mill at Huntington, West Va., has been appointed assistant director of technical service to succeed Mr. LaQue.

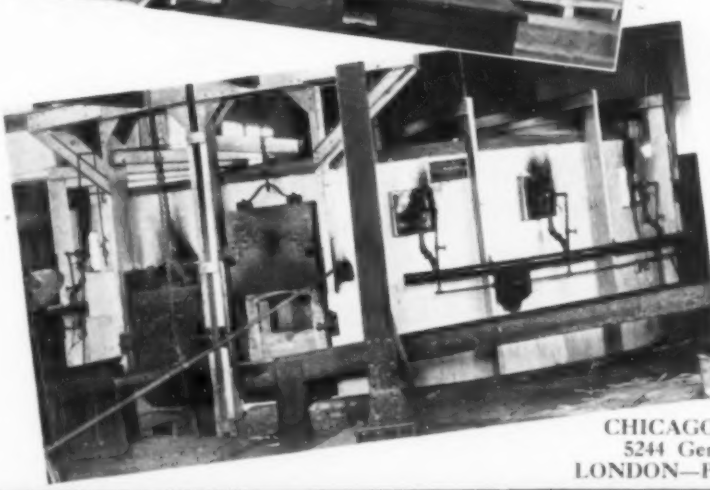
Harold H. Strauss is now structural engineer with Curtiss Aeroplane Division, Curtiss-Wright Corp., Buffalo, N. Y.

Ramon D. France is now with Frankford Arsenal, Philadelphia, as metallurgist.

Lauren P. Wood is head of the materials department, Aviation Mfg. Corp., Stinson Aircraft Division, Wayne, Mich.

"Salem" ROTARY HEARTH FURNACES are Versatile





It is something to consider—that a furnace, admirably fitted to pressure production, may later be perfectly adapted to diversified commodity production—and with little or no change.

"Salem" Rotary Hearth Furnaces are like that—adaptable—a long time investment—sure to pay out.

"Salem" Rotary Hearth Furnaces have their own special advantages too:—

(1) The Rotary Hearth is self-emptying—compared to the pusher type where the furnace is always loaded.

(2) The Rotary Hearth offers fuel economy due to small doors and compared with batch type furnaces.

(3) With the Rotary Hearth, steel is kept moving—never left standing long under direct flame.

(4) The Rotary Hearth offers more ideal loading and heating conditions.

Upper right—Controlled oil-fired Salem Rotary Hearth Furnace used primarily for high speed steel billets up to 9½" square by 50" long.

Upper left—"Salem" Rotary Hearth fuel fired furnace for hardening skate blades and bicycle wheel races. This furnace employs balanced hearth trays of alloy steel which tip forward permitting discharge of material into either water quench or oil quench.

Second from top left—"Salem" Rotary Hearth Furnace 14 ft. in diameter for hardening coil springs, operates at around 1500 degrees Fahr. Fuel oil-fired, provides uniform temperature throughout for heat treating.

Second from bottom—Rotary Hearth Furnace 20 ft. in diameter used for heat treating rail splice plates; furnace capable of operation at 2000 degrees Fahr. when desired.

Bottom—Fuel fired "Salem" Rotary Hearth Furnace for heating and drawing shell forgings.

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SALEM ENGINEERING COMPANY

Personals

Gerard H. Boss is doing some graduate work in the school of metallurgical engineering, University of Michigan.

Promoted by Timken Steel & Tube Division: **Donald S. Klippert**, formerly sales engineer in Chicago, to district manager of steel sales in Cleveland.

R. M. Paxton, Jr., who has been appointed manager of the new export office recently established by Jessop Steel Co., in New York, also remains in charge of domestic business at the same office.

Andrew McCance, director and general manager of Messrs. Colvilles, Ltd., Glasgow, Scotland, has been awarded the Bessemer Gold Medal for 1940 by the British Iron and Steel Institute.

S. V. Cuthbert, formerly in the sales department of J. T. Ryerson & Son, Inc., Jersey City, N. J., is now warehouse salesman of alloy and stainless steel for Crucible Steel Co. of America, Harrison, N. J.

George J. Frame, formerly heat treater at South Chester Tube Co., is now a temperer at the Philadelphia Navy Yard.

Elected by International Acetylene Association: President—**Henry Booth,** vice-president, Shawinigan Products Corp.; vice-president—**E. L. Mills,** vice-president, Bastian-Blessing Co.; treasurer—**Philip Kearny,** president, K-G Welding and Cutting Co.; secretary—**H. F. Reinhard** of Union Carbide Co.

Transferred by Carnegie-Illinois Steel Corp.: **C. Robert Lillie**, from junior metallurgist in the Gary sheet mill to metallurgist at the research laboratory in Pittsburgh.

Frederick F. Shoemaker is now in charge of a project for pressure die casting of gray and malleable iron at the Research Foundation of Armour Institute of Technology, Chicago.

Erle Ross, engineering editor of **Steel,** has been elected president of the Indiana Club of Cleveland.

Louis M. Benkert has been named general manager of Progressive Welder Co., Detroit.

Added to the sales staff of McKenna Metals Co., Latrobe, Pa.: **F. E. Doty,** in charge of the Houston, Texas, territory; **C. W. Moore** in charge of the Atlanta, Ga., branch office.

Selected by the Advertising Club of New York for the honorary society of the Order of the Rake: **Gordon Tuthill,** advertising manager of the Crucible Steel Co. of America.

Morgan B. Smith has been added to the technical organization of the Detroit Testing Laboratory for consulting practice.

Personals

Glen R. Ingals is back as metallurgist for Reed Roller Bit Co., Houston, Texas, after a leave of absence.

Paul Klain, formerly research metallurgist at Battelle Memorial Institute, Columbus, Ohio, is now metallurgist at Dow Chemical Co., Midland, Mich.

Frederick G. Hughes, past president, general manager of New Departure Division of General Motors Corp., Bristol, Conn., was recently presented one of the Modern Pioneers Awards of the National Association of Manufacturers.

Norman L. Deuble, formerly metallurgist, Republic Steel Corp., is now associated with Copperweld Steel Co. at Warren, Ohio, as assistant to the vice-president.

William B. Hurley, formerly with Detroit Edison Co., has been appointed assistant district chief of the Detroit Ordnance District, of the U. S. Army.

F. T. Llewellyn, recently retired after almost 50 years with American Bridge Co. and Carnegie Steel Co., has been awarded a certificate as an honorary member of the American Welding Society.

Henry J. Fischbeck, chief metallurgist for Pratt & Whitney Aircraft Division of United Aircraft Corp., has been promoted to the position of process engineer.

John J. Crowe, formerly manager of the apparatus research and development department of Air Reduction Co., has been appointed assistant to **Herman Van Fleet**, vice-president and operating manager. **H. E. Landis, Jr.**, formerly assistant to Mr. Crowe, has been appointed manager of the apparatus research and development department.

Gordon J. LeBrasse, research associate on the Bureau of Standards' American Silver Producers' Research Project, has accepted a position in the laboratory of the Federal-Mogul Corp., Detroit.

W. A. Olsen, previously connected with SKF Steels, Inc., is now with Uddeholm Co. of America, Inc., as manager in charge of toolsteel.

E. H. Dix, Jr., chief metallurgist of Aluminum Research Laboratories, New Kensington, Pa., spent about a month recently visiting aircraft companies on the West Coast, where he addressed various groups of engineers on theory and practice of heat treating aluminum alloys.

D. J. Doan, research metallurgist, the Eagle-Picher Lead Co., formerly in the laboratory at Joplin, Mo., has been placed in charge of the new laboratory recently established by the company at Cincinnati.

Arc Welding Fluxes

By W. Andrews

IN AN ARTICLE entitled "Some Observations on Metallic Arc Fluxes" in *The Engineer* for March 8, 1940 (page 224) Mr. ANDREWS confines himself to coatings on British-made electrodes designed to weld mild steel only, with 0.25% max. carbon. The coating fulfills a variety of functions, among which the most important are *(a)* controlling the electrical characteristics of the arc; *(b)* modifying the mechanism of metal fusion and consequently transmission across the arc; *(c)* inhibiting reactions in the metal during its passage through the arc, and *(d)* controlling the shape and surface finish of the bead. In addition to these technical reasons, the operative and economic factors are also extremely important.

The earliest fluxes often consisted of simple mixtures of iron oxide and silicates. The fact that such compounds occur naturally as blue asbestos led to their extensive use as a flux in itself, and the ease with which it could be applied as a close cord winding gave it considerable popularity. While such electrodes are still on the market, most modern coatings consist of a mixture of minerals, chemicals and ferro-alloys bonded with sodium or potassium silicate solution. Many methods of coating a wire are possible and are in use, such as dipping the wire in a slurry, or pressing, rolling or extruding a stiffer mixture through a die. Most British electrodes are coated by extrusion. If the flux does not form a smooth-flowing paste, some organic compound is incorporated to condition it for extrusion — one that vaporizes easily during welding without effect on the quality of the weld metal.

While most formulas remain manufacturer's secrets, the most used substances are mineral silicates, ferro-alloys, metallic oxides, fluorides, and carbonates, together with organic compounds, apart from those used to assist extrusion. Economic conditions demand that the materials should be plentiful and reasonably cheap and this is the reason that natural minerals, rather than prepared chemicals, are more frequently used.

Two main divisions of electrode coatings must be recognized, those which act as arc stabilizers only and the true fluxes. Arc stabilizers are $CaCO_3$, TiO_2, and other carbonates, applied as a very thin wash in too small a quantity to act as a true flux. They are applied purely for electrical reasons, and

have long been substantially displaced from important work. Owing, however, to the difficulties encountered in the combination of an adequate flux with a continuous automatic welding process a fair amount of welding is still done with them.

Fluxes may also be classified by method of manufacture:

I. Dipped process; *(a)* wash coatings, which have just been described, and *(b)* heavy dipped coatings wherein several dips are given to attain a coating thickness of the same average as on extruded electrodes.

II. Wrapped electrodes; *(a)* single coatings with materials such as blue asbestos which lend themselves readily to application to the electrode as a yarn winding; and *(b)* double coatings, the outer one being similar to II*(a)*, and the inner a paste or other type.

III. Wound and extruded, with cotton, various types of asbestos, paper or other cellulosic material, all of which may be reinforced with wire, or wire itself may be employed. The winding agent forms an open spiral round the rod and the flux is extruded into the spaces by passage through a die under pressure.

IV. Plain extruded, wherein a paste is extruded directly onto the rod, forming an uninterrupted sleeve of flux. Very stiff pastes and high pressures are usually employed and a smooth intense arc obtained. Rods of this type are difficult to bend without breaking off the coating.

True fluxes in addition to exercising their effect on the electrical characteristics of the arc are employed for their metallurgical and mechanical effect on the deposit. According to whether they contain cellulosic matter and are of the so-called gas shielded type, or rely on the fluxing properties of the chemicals or minerals they contain, they fall into: 1. Slag shielded types and 2. Gas shielded types.

In the following classification by constituents in the flux, the constituent sub-heading gives type constituents only; for instance, where "titanium oxide, silica, alloy" is quoted, it is intended to convey that a metal oxide of the titanium type is used in conjunction with some silicate-bearing mineral or minerals in combination, and the possible variations in composition are almost infinite.

Slag Shielded Arcs

1. Iron oxide, silica: Mixtures of various iron oxides and silica or silicates are used in various proportions. Blue asbestos wrapped electrodes also come into this classification, though in this case a compound instead of separate constituents is used. The coating is oxidizing and in consequence the weld metal con-

(Continued on page 582)

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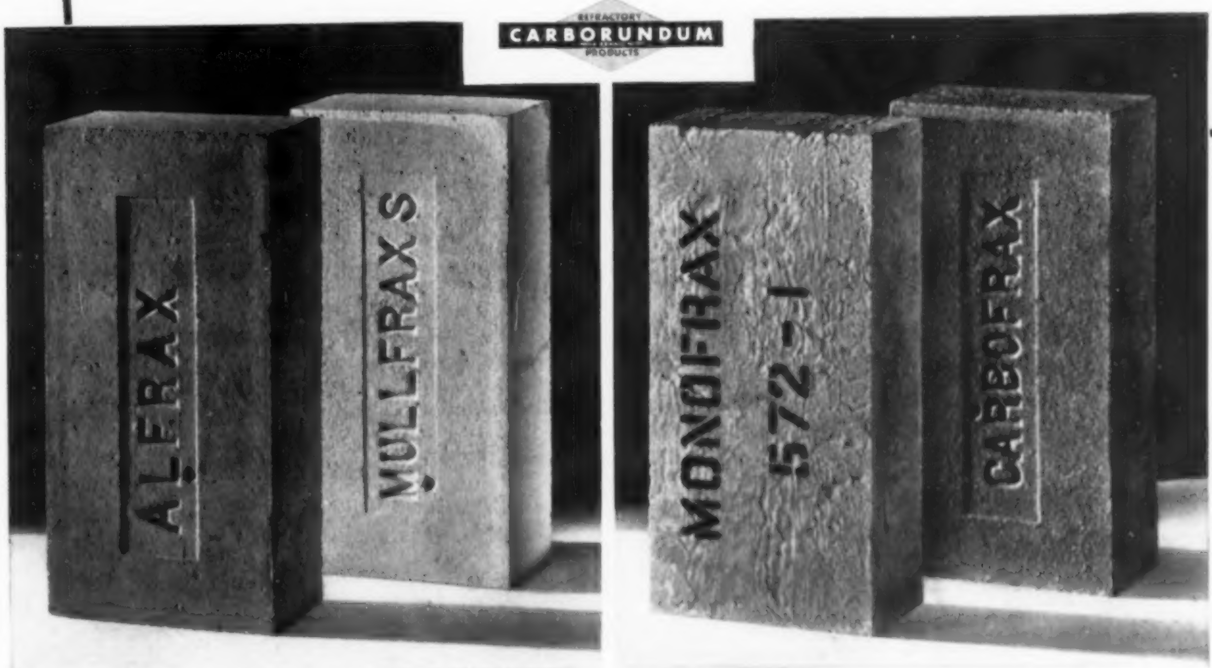

Welding Fluxes

(Continued from page 579)

tains little or no manganese and is low in carbon. It thus approximates pure iron in composition, though porosity and slag inclusions may be frequent. Electrodes of this class are usually sold because of the running properties and finish obtainable on the weld metal.

2. Iron oxide, silica, alloy: Basically similar to group 1, just above, but of wider scope, less oxidizing in nature and often modified by carbonates and other oxides. Electrodes of this class contain deoxidizing ferro-alloys, usually ferromanganese, and as a result the weld metal composition approaches that of ordinary mild steel. The slag of this type of weld metal is usually inflated and very easily removed.

3. Titanium oxide, alloy: Titanium oxide, usually in the form of rutile, forms a large proportion of the flux, together with ferromanganese and other alloys and fluxing constituents, such as silicates. The high rutile content results in flat surface deposit of excellent appearance and a solid slag, easily removed.

4. Titanium oxide, silica, alloy: Differs from the previous class of rod in that on the average much less titanium oxide and more silicates are used. The result is a slag of greater adaptability for welding in all three positions.

5. Fluoride and other chemicals: Fluorides are typical of neutral materials which may be used to make an effective flux. Fluorspar is a common example. They are little used in the case of mild steel, though useful in non-ferrous metals and special alloy steels.

Gas Shielded Arcs

This term applies to electrodes in which in addition to a mineral slag an organic material of the cellulose class is incorporated. This organic material is said to decompose into carbon monoxide and hydrogen, surrounding the arc with a reducing atmosphere and thus excluding oxide and nitride contamination. In consequence the oxidizing non-alloy types are not represented in this class, nor do fluoride fluxes find any appreciable favor in conjunction with such material. Gas shielded electrodes, therefore, usually fall into the three middle classes of the slag shielded types noted above as 2, 3 and 4.

It is claimed that so much hydrogen from cellulose increases the electrical resistance to the arc, and a quicker welding. Observation suggests that there is little to choose between high quality electrodes, with or without gas shielding, for the making of clean and strong deposits.

Sculpture in Stainless

(Continued from page 540) polish or "butler finish" similar to that on fine silver. Because of its great area, however, and the fact that it reflected lights from all sources or subjects even at a great distance, it was finally decided to rough grind the entire surface in a variety of angles to break up light reflections. Practically all of the final finish was done by the sculptor himself. He used portable, electric driven grinders, so arranged that the peripheral speed at the cutting edge of each grinding wheel, irrespective of its diameter, was the same. We believe this coarse ground finish, arranged to mottle any direct light reflection, is unique.

Because men are not accustomed to large areas of light-reflecting material it is impossible to visualize this plaque. It presents to the photographer the most difficult photographic subject yet encountered, for it is common knowledge that even small objects which reflect light, like table silver, are extremely difficult to photograph. Consequently the view on page 536 is inadequate.

After dis-assembly for shipping, the plaque was passivated with a hot solution containing nitric acid to remove all traces of abrasives, iron contamination from tools, and other foreign materials. More than 200 gal. of ammonia sprayed on at 200 lb. pressure neutralized the acid. It was then washed with several thousand gallons of hot water, hauled in a street sprinkler from a nearby steam laundry.

From a metallurgical standpoint, the production of this plaque is obviously important, not so much for the size as for the fact that it is the *first* application of large stainless castings to architectural ornamentation. There was no former experience with similar items more than a fraction of the size and weight of one section of this job. The constantly high order of New England craftsmanship took this one in its stride — not a single one of the nine parts was lost.

The American steel industry has mammoth facilities for the low cost production of stainless steel decorative moldings such as used on all leading automobiles, and all types of rolled and formed sheets, bars and tubes. Before these can have wide use in architecture they must be supplemented and complemented by more pleasing forms — just as bronze and aluminum bars and other mill products are combined with castings in molded form to make functional and ornamental design in architecture. Ornamental bronze founding is as old as history, but the casting of stainless steel in ornamental form is a new art, opening a wide field. *(Continued on page 590)*

DU PONT research has brought to the Steel Treating Industry not only new and improved materials for immediate use, but also other materials and processes which anticipate the requirements of the industry. And because these new materials are cheaper, better and easier to use, they are helping the industry in its progress towards reduced costs and improved products.

Research is not confined to the laboratory. It is brought into the shop by a group of skilled specialists—technical men with many years of practical experience in steel treating. In this way du Pont applied research provides manufacturers with an opportunity to improve their products and methods, to lower costs, and to keep ahead of the ultimate needs of their customers.

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Sculpture in Stainless

(Starts on page 536)

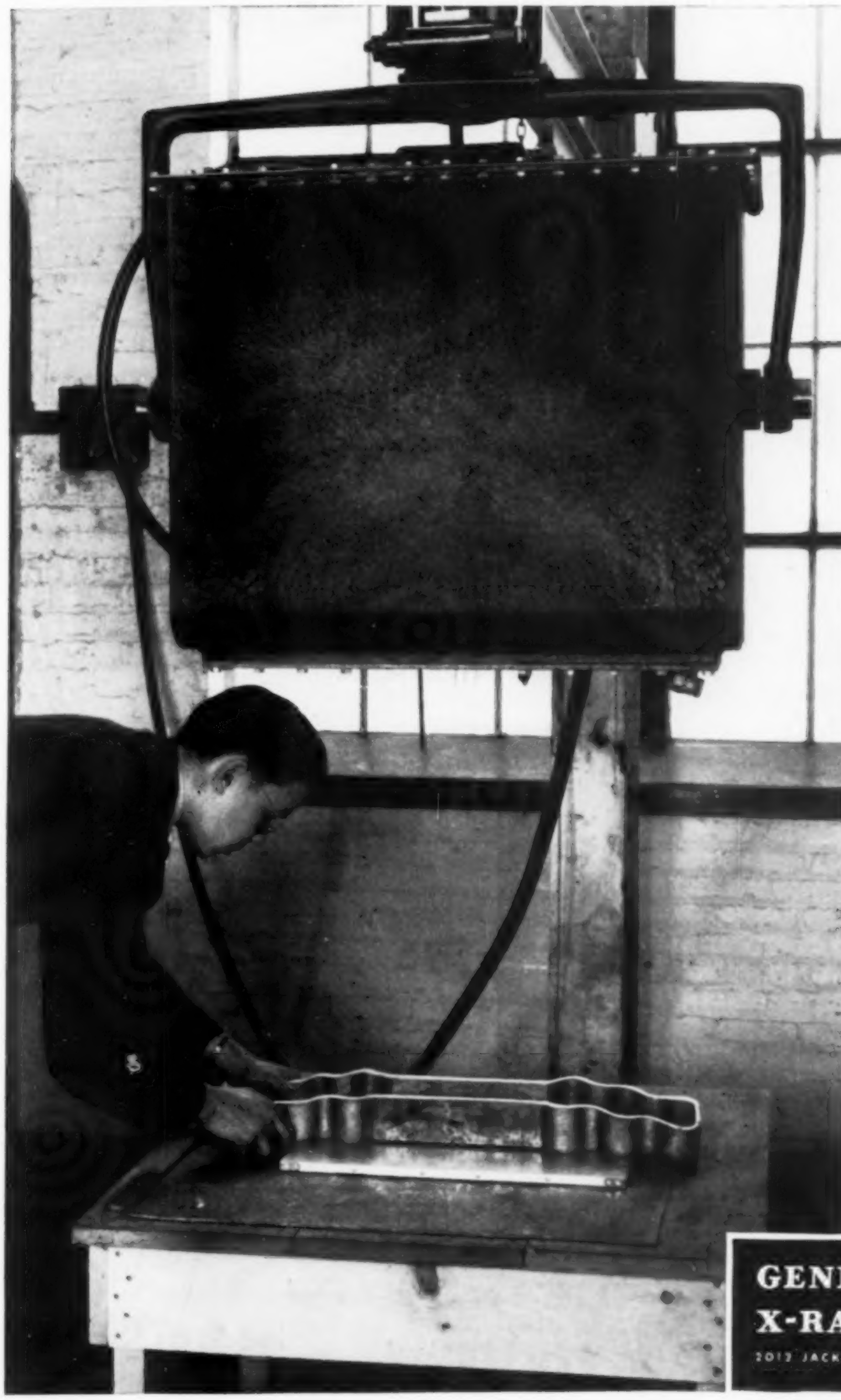
Perhaps the greatest architectural significance of this contribution of Rockefeller's is the introduction of fully molded forms in light *reflecting* materials into a field almost exclusively dominated by light absorbing materials which rely on *shadow* for contrast.

Barring a few gold pagodas of ancient time, man has never modeled large areas of light reflecting metals. Man's outstanding works in light reflecting metals are products of the armorer, the silversmith, and the jeweler. These supercraftsmen, working in materials and articles personal and artistic in character, leave a far richer heritage of ornament and motif than the stone and wood carvers and the bronze founders of architectural ornament. Architectural ornament has stemmed largely from fragments of temples built to dead gods, executed in monotone, light absorbing media — in fact, degeneracy of architectural ornament brought about the reactionary severity of much modern architecture.

Thus, architecture finds in armor, silver and jewelry a new and rich source of design inspiration in light reflecting materials. Design cannot be lifted bodily from these arts into architecture. Much study, effort and experience have gone into developing the strong clean functionalism of modern buildings. The premise, "that which is truly functional is truly beautiful", is widely accepted. If the same degree of logic and understanding exhibited by leading American architects is applied to the introduction of stainless steel into architecture, all will benefit.

Modern architecture, primarily functional, is eliminating much of the ornamentation for enrichment's sake which "adorned" many older buildings. However, sculpture should find a new and greater place through stainless steel. It will add interest and aesthetic value to architecture, providing an adornment of higher integrity. It seems obvious that non-corrosive steels will eventually replace soft and painted metal exposed to weather. First costs are absorbed by maintenance savings in a very few years.

Making the Noguchi plaque for Rockefeller Center has been for us a privilege and an experience. Congratulations have showered upon us from leaders in the steel and automotive industries, from architects, metallurgists, journalists, and others. The statement from which we derive greatest pride comes from one of the few statesmen in Washington, who says, "This bright new symbol of America's Free Press is the most significant casting since the Liberty Bell."



Notes About Contributors

MEN in Henry Ford's organization function without having fancy titles. Most of them are modest to a fault. When asked for portraits and biographical notes of the authors of our leading article on "Cast Steel Parts for the Ford Tractor", Mr. McCarroll wrote "We suggest the biographies would be of little interest." On the contrary, so many metallurgical innovations have come from the Ford plant that other ASMembers would like to know some of the men who are responsible. Metallurgical and chemical work throughout the Rouge plant heads up to **R. H. McCarroll** and has for as many years as the Editor knows. **E. C. Jeter** is a metallurgist working under Mr. McCarroll's direction.

The pen-and-ink cover for this issue was submitted by **Carl Sorensen** in a competition for the March Anniversary Issue, and therefore emphasizes the progress in metallurgy from the wood burning locomotive to the gas-engined airplane. Mr. Sorensen was employed for a number of years by Powers-House Co., the Cleveland advertising firm that acted as art director of METAL PROGRESS in its early days. He is now a free lance in advertising — and deeply enjoys his hobby, which is music.

The dynamic **Henry H. Harris**, known to everyone in the heat treatment field as "Harry", writes on page 536 with justifiable pride about an enormous stainless steel plaque cast in his foundry. He printed a brief and pithy autobiography in his advertisement in METAL PROGRESS last November from which the humdrum facts are drawn that he became a War-time flyer that never got closer to the front than Texas, then studied engineering and metallurgy at Wisconsin. He promoted Q-Alloys for Quigley Furnace Specialty Co. until he bought the complete rights and organized General Alloys Co., later moving to Boston (1923). He was a member of the Editorial Board for METAL PROGRESS in 1935 and 1936 and the Editor hereby acknowledges the improvement in the reading pages resulting from his unsparing criticisms, but regrets that a similar effect is barely discernible from editorial animadversions on Harry's advertising.

Henry H. Harris

Carl Sorensen

Though ably written by **Adolph J. Scheid, Jr.**, metallurgist for Columbia Tool Steel Co., Chicago Heights, Ill., the article on chemistry of electric steel making is nevertheless a report of work done and papers presented by **C. H. Herty, Jr.** and **C. E. Sims.** As most ASMembers and METAL PROGRESS readers know, Dr. Herty is an authority on this subject as the result of work beginning in 1926 on the staff of the U. S. Bureau of Mines, assigned to the Pittsburgh studies into the physical chemistry of steel manufacture. Dr. Herty is now research engineer for Bethlehem Steel Co.

C. E. Sims, research metallurgist at Battelle Memorial Institute, has given many years to the study of slag reactions and their resultant effect on types of inclusions and physical properties of steel. Many of these studies were made at the time Mr. Sims was assistant director of research with American Steel Foundries (1927 to 1936).

Walter A. Dean has been a research metallurgist with the laboratories of the Aluminum Co. of America ever since his graduation (B.S. from Cooper Union, 1926; M.S. and Ph.D. from Rensselaer, 1929).

Photographic artist **Van Fisher** found crucible steel (page 543) one of the most interesting subjects yet in his series of pictorial stories that was largely responsible for METAL PROGRESS's winning *Industrial Marketing's* award in this field last year. Mr. Fisher's career was noted in the June 1938 issue.

When it's a question of reducing machining costs and stepping up production (on jobs where high speed steel is the indicated cutting tool), you'll find the answer in CIRCLE "C". It will give desired results through at least 25% faster machine operation, greatly increased cuts and feeds, extra long production between grinds. Satisfyingly longer tool life compensates for the somewhat higher initial cost.

Additionally, CIRCLE "C's" carefully balanced cobalt-tungsten analysis assures profitable operation on the critical, harder alloys . . . hence its success with typically tough jobs involving aeroplane motor parts, bearings and the like. The more quickly you find out about this unusual high-speed steel the better . . . for savings' sake. Full information is yours for the asking. Ask now!

Firth-Sterling's companion lines of Sintered Carbides and Tool Steels make available a Complete Shop Tooling Service through one experienced organization.

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HELPFUL LITERATURE

● ***Some of the foremost experts in the metal industry have contributed to the wealth of information contained in the literature described on this page. You will find your time well spent in looking it over. One booklet may solve your most difficult problem. Use the convenient coupon today to obtain this free literature.***

Measuring Metal Coatings

Measurements of local thicknesses of coatings on metals may be made in less than one minute by the Magne-Gage, an interesting instrument described in a 4-page folder by the American Instrument Co. Bulletin Cd-259.

Industrial Furnaces

A series of interesting bulletins showing Dempsey Industrial Furnaces in a wide range of requirements is now available through the Dempsey Industrial Furnace Corp. Bulletin Dd-260.

Colmonoy

The high resistance to wear and corrosion which distinguishes Colmonoy alloys and overlay metals is explained in a 4-page catalog released by Wall-Colmonoy Corp. Bulletin Bc-85.

Steel Catalog

Helpful to all designers, engineers and fabricators interested in the use of high tensile, low alloy steel is a new 40-page catalog on Republic Double Strength Steel. Bulletin Dd-8.

Electric Furnaces

A four page bulletin on ¼ lb. to 4 lb. high frequency melting furnaces and 3 kw. converter is now available through the Ajax Electrothermic Corp. Bulletin Dd-41.

Aerocase

A modern method for case hardening and heat treating steel in a liquid bath is provided by the use of Aerocase compounds. Their principal features are described by American Cyanamid and Chemical Corp. in an interesting booklet. Bulletin Oy-148.

Galvanizing

An informative, historical, simple digest of galvanizing forms a guide to longer life for iron and steel products. This handsome, handy, 24-page book beautifully printed in color is distributed by American Hot Dip Galvanizers Association, Inc. Bulletin Ea-167.

High-Strength Steel Data

Complete mechanical property data on Ductiloy, a new low-alloy, high-strength steel, are given for strip, plate and bars in a folder of Great Lakes Steel Corp. Bulletin Ec-229.

Ingot Production

"The Ingot Phase of Steel Production" is the title of a book defining the principles of quality ingot production followed by many well-known steel manufacturers. Gathmann Engineering Co. Bulletin Ka-13.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Heroult Furnace

Revised and expanded to include modern major innovations in the construction and operation of the Heroult electric furnace, the latest edition of the American Bridge Co.'s Heroult Electric Furnace Bulletin is available. Bulletin Bb-124.

Seamless Tubes

Prepared by the Timken Steel and Tube Division of Timken Roller Bearing Co. is a "Guide for Users of High Temperature Steels" which presents technical data relating to the various properties of Timken seamless tubes. Bulletin Bb-71.

Metal Heating

Improvements in furnace economies, operating conditions and appearance, furnaces that will more satisfactorily meet old requirements or handle new processes, service that will help solve the most stubborn problems are offered and described by Mahr Mfg. Co. in Bulletin Ea-5.

Mounted Wheel Chart

A convenient ready reference wall chart showing mounted grinding wheels should be of great advantage in the cleaning room, pattern shop, tool and die room, and many other places. It gives at a glance, by means of detailed drawings, actual size, the exact radius of each wheel and its exact shape. Chicago Wheel & Mfg. Co. Bulletin Bd-230.

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Insulation

A 32-page catalog containing specific information on all of the sheet, block and pipe insulations developed by the Johns-Manville Company is now available through that company. Bulletin Fb-100.

Heat Treating Hints

A helpful, colorful booklet edited by experienced heat treaters is available through the Lindberg Engineering Co. Bulletin Bd-66.

Moisture Determination

A very colorful leaflet by the Harry W. Dietert Co. describes new, rapid methods of determining moisture content by drying. Illustrated. Bulletin Cd-198.

Free Machining Steels

Speed Case and Speed Treat, two steels with increased machining properties, are described in literature available through Monarch Steel Co. Bulletin Cd-255.

Low-Alloy Steel

A new folder on Mayari R, Bethlehem's high-strength, corrosion resisting steel, is colorfully illustrated with views of its various uses. Bulletin Kc-76.

High Speed Steel

Required hardness and extraordinary toughness combine to make Firth-Sterling Co. new high speed steel "Mo-Chip" of unusual interest to manufacturers who need a steel that is "practically indestructible." Bulletin Ad-177.

Oil Burners

North American Mfg. Co. offers a bulletin describing improved low pressure oil burners, one type especially designed for automatic control and ideally suited for use with proportioning control valves. Bulletin Na-138.

Tocco Junior

A new induction hardening machine for hardening small parts is described in a new bulletin released by the Ohio Crankshaft Co. Bulletin Dd-145.

Steel Data Sheets

Wheelock, Lovejoy & Co. gives analyses, physical properties, heat treating instructions, and applications of Hy-Ten, Economo, and S.A.E. alloy steels in concise and easily usable form. Bulletin Ox-74.

HELPFUL LITERATURE

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Tool Care

A new catalog on Kennametal tools for machining steel and other metals is valuable to anyone interested in better machining results. McKenna Metals Co. Bulletin Ed-238.

Metal Welding

Of particular interest to the aircraft industry and all fabricators of light-gauge metal will be the new booklet "Sheet Metal Welding Fundamentals" released by the Linde Air Products Co. Bulletin Ed-63.

Carburizing Furnace

The new Homocarb Furnace which gives a carburized case of unusual speed and certainty is described in a new booklet by Leeds & Northrup Co. Bulletin Ed-46.

Welding Stainless Steels

A 24-page technical bulletin, giving important information for the engineer, designer or welding operator on the welding of stainless steel, is available through the Arcos Corp. Bulletin Hc-191.

Tool Steel Chart

A valuable Tool Steel Guide Chart for Shop Use is offered by William Jessop & Sons, Inc., makers of tool steels of every description. Bulletin Ed-61.

Lubrication

Intensive research which completed important improvements in the field of heavy-duty gear and bearing lubrication is tabulated in a new 12-page illustrated bulletin just released by D. A. Stuart Oil Co., Ltd. Bulletin Lb-118.

Oil Burners

A new model proportioning oil burner giving accurate combustion and temperature control with greater fuel economy is described in a booklet by the Hauck Manufacturing Co. Bulletin Ed-181.

Heat Fans

A complete line of fans for high temperatures are illustrated and accompanied by detailed specifications in the colorful booklet available through the Garden City Fan Co. Bulletin Ed-261.

Portable Electric Furnace

A unique portable electric furnace designed for use at temperatures below 1100° F. with drawing salts and oil tempering baths is described in a booklet by Claud S. Gordon Co. Bulletin Ed-53.

Process Control

"Stabilflo Valves", an illustrated folder just issued by The Foxboro Co., describes this rugged, yet extremely accurate, valve for use in process control. Bulletin Ed-21.

Steel Castings

Steel castings made under laboratory control are described in a folder just released by the Dodge Steel Co. Bulletin Ed-263.

Indirect Air Heater

A new indirect air heater which many combustion engineers claim as the most important development in 20 years is described in a folder by the Despatch Oven Co. Bulletin Ed-123.

Case Histories

Factual and practical data plus four "case histories" of REXALLOY'S superior cutting performance is contained in literature just made available by the Crucible Steel Company of America. Bulletin Ed-56.

Precision Saws

The complete selection of DOALL precision saws supplied by Continental Machines, Inc., is shown in an attractive folder supplied by this company. Bulletin Ed-170.

Bright Annealing

Various types of electric and fuel-fired furnaces built by the Electric Furnace Co. for bright-annealing wire, tubing, strip and other products are described in an 8-page folder. Bulletin Lb-30.

Casting Practice

The Detroit Steel Casting Co. has a pictorial presentation of the casting process in their plant which should be of interest to manufacturers interested in quality steel castings. Bulletin Ed-262.

Metallographic Equipment

The 100-page "Metal Analyst" issued by Adolph I. Buehler features new Metallographic Sample Preparation Equipment; a comparative listing of Metal Microscopes, Measuring Microscopes, and Spectrographs; an index of over 1,000 new technical books and papers; and a treatise on the Application of Reflected Light. Bulletin Ed-135.

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Strain Gages

A description of strain gages and extensometers handled by Baldwin-Southwark is included in an attractive bulletin just issued. Bulletin Ed-67.

Tuf-Wear Steel

A neat little 24-page booklet describing special alloy steels which have been developed for the oil and other industries is available through the Oklahoma Steel Castings Co. Bulletin Ed-257.

Temperature Control

The new G-E Reactrol system of exact temperature control is explained in a new bulletin made available by General Electric Co. Bulletin Ed-60.

Clean Hardening

Continuous clean hardening machines for work ranging from extremely small, light springs, stamping, drop forgings, etc., up to quite large and heavy pieces are described in a bulletin by the American Gas Furnace Co. Bulletin Ed-11.

Degreaser

Degreasing machines for practically every cleaning job are described in literature made available through the Detroit Rex Products Company. Bulletin Hc-111.

Brazing Furnace

If you have a brazing problem you will be interested in the worthwhile folder issued by Hoskins Mfg. Co. Bulletin Ec-24.

Vanadium Steel

Latrobe Electrite Vanadium High Speed Tool Steel is described in literature released by the Latrobe Electric Steel Co. Bulletin Kb-208.

Industrial Furnaces

Furnaces of all types are fully described in technical bulletins made available by the Eclipse Fuel Engineering Co. Bulletin Ec-226.

Cutting Oils

An interesting new booklet "Metal Cutting Lubrication — In Theory and Practice" has just been made available by Cities Service Oil Co. Bulletin Ec-113.

Closer Temperatures

Closer temperature control than is possible with any Mechanical Controller is explained in a 12-page illustrated pamphlet just released by Wheelco Instruments Co. Bulletin Nc-110.

HELPFUL LITERATURE

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Lectrodryer

A machine designed specifically for the dehumidification of air and other gases as well as certain liquids—the "Lectrodryer"—is pictured and explained in a booklet by the Pittsburgh Lectrodryer Corp. Bulletin Gc-187.

Ferrocarbo

A cupola addition, "Ferrocarbo", which improves casting quality, lowers costs and reduces rejects is described in literature available through the Carborundum Co. Bulletin Bd-57.

Pure Metals

Pure, carbide-free metals are described and applications suggested in a pamphlet published by Metal & Thermit Corp., who make pure tungsten, chromium and manganese in addition to the ferro-alloys. Bulletin Ma-64.

Ferro-Alloys

An interesting folder by Electro Metallurgical Co. tells all about their ferro-alloys and their special service to users which will help them to operate their furnaces and make alloy additions under the proper conditions. Bulletin Jy-16.

Conjecto-Firing

A wider temperature range and closer control, known as Conjecto-Firing, is now available in Surface Combustion furnaces. A four-page leaflet describes the advantages of this system. Bulletin Ed-51.

Aluminum Finishes

A new booklet which lists the finishes available for various forms of Alcoa Aluminum Alloys has just been released from the press by the Aluminum Company of America. Bulletin Ed-54.

Annual Index

The Annual Index of the Copper Alloy Bulletin published regularly by the Bridgeport Brass Company is now made available through this company. Bulletin Kc-163.

Foundry Sand

A pamphlet recently issued on TAM Foundry Zircon Sand and TAM Zircon Flour contains detailed information on these products of the Titanium Alloy Mfg. Co. Bulletin Hc-90.

Moly in Steel

Metallurgists, engineers and production executives who are really interested in the metallurgy of steels and their application will want the excellent book on molybdenum steels published by Climax Molybdenum Company. Bound in looseleaf manner, this reference book is chock-full of tables which form a volume almost an inch thick. Bulletin Hb-4.

Metcolizing

Actual photomicrographs illustrate the action of high heat corrosion on a Metcolized surface in the bulletin by Metallizing Engineering Co., Inc., describing this new and efficient method of applying a coating of aluminum to iron or steel. Bulletin Ed-267.

Meehanite Wheel Chart

A handy wheel chart which contains complete engineering data about all the various types of Meehanite castings available to industry has been prepared by the Meehanite Research Institute of America. It quickly reveals the physical properties of general engineering castings as well as heat, corrosion and wear resisting types. Bulletin Dd-165.

Ramix

Ramix is a prepared magnesite refractory made by Basic Dolomite, Inc. An interesting folder gives full information on its uses in basic open-hearth and basic electric furnaces, and in various non-ferrous furnaces, along with complete instructions for installing. Bulletin Dd-192.

Salt Bath Furnace

"As modern as radio-beam control" says the attractive folder put out by Commerce Pattern Foundry & Machine Co. about the Upton electric salt bath furnace. A brief but informative article on "The Importance of Temperature" by R. C. Upton is included. Bulletin Ed-266.

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New X-Ray Unit

A new X-ray diffraction unit, smaller and more versatile than previously available outfits of this type, is described in a comprehensive folder released by the General Electric X-Ray Corp. Bulletin Hc-6.

Furnace Alloys

Standard Alloy Co. emphasizes the necessity, brought about by the use of high temperatures in heat treating, for an alloy that will do its particular job at the lowest cost. An attractive booklet, illustrating and describing various types of alloy casting for heat and corrosion resistance. Bulletin Ad-151.

Inconel

The properties and uses of "Inconel," a corrosion-resisting alloy of approximate composition 79.5% Ni, 13% Cr, and 6.5% Fe are discussed in a valuable technical bulletin made available by the International Nickel Co., Inc. Bulletin Cc-45.

Hot Pressed Parts

Hot Pressed Parts and Pressure Die Castings made with substantial savings over other methods are described in an 8-page booklet released by the American Brass Company. Bulletin Cc-89.

Processing Materials

A complete line of processing materials, including pack carburizers, reheating salts, quenching oils, drawing salts, cutting oils, etc., is described in an attractive folder by G. S. Rogers & Co. Bulletin Ed-265.

Machinery Steel Selector

A handy chart giving complete physical characteristics with variations up to 8" cross-sections, machining data, etc., on the ELASTUF group of Related Machinery Steels is available through Horace T. Potts Co., Brown-Wales Co., and Beal McCarthy & Rogers. Bulletin Ed-264.

Rotoblast

Several unusual features make the Pangborn Rotoblast of more than ordinary interest to manufacturers with a metal cleaning problem. Described in booklet by the Pangborn Corp. Bulletin Ed-68.

HELPFUL LITERATURE

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Cadalyte "38"

A new technical service manual on CADALYTE "38" for cadmium plating has been issued by the Electroplating Division of du Pont. Cites recent improvements and changes in the product, and gives detailed operating instructions and methods of analyses. A table of costs and time required for specified deposits is included. Bulletin Gb-29.

Electric Furnaces

Holcroft & Co. have a 30-page booklet which tells the story of a score of representative furnace installations, giving production records, operating data and furnace description. Bulletin Kb-203.

Electric Salt Bath Furnaces

Users' reports on work treated in the Ajax-Hultgren salt bath furnace are described and operating data for cyaniding, carburizing, hardening high speed steel, etc., are given in literature of Ajax Electric Co., Inc. Bulletin Cd-43.

Machinability Chart

A quick and accurate picture of how Rustless Stainless Steel will respond to your shop operations is given in the "slide-rule" machinability chart available through the Rustless Iron & Steel Corp. Bulletin Bd-169.

Specialized Tester

The Rockwell superficial hardness tester is a specialized instrument for use where the indentation into the work must be kept shallow or of small area, yet sensitivity preserved. A supplement to Wilson Mechanical Instrument Co.'s catalog on the regular Rockwell tester tells all about it. Bulletin Sy-22.

Vacuum Cleaning

A very colorful brochure which illustrates modern cleaning methods by vacuum in industrial plants has been released by The Spencer Turbine Co. Bulletin Dc-70.

Microscope Accessories

A 62-page catalog with index and price list describes and illustrates all sorts of microscope accessories, including a wide variety of objectives and eye pieces, made by Bausch & Lomb Co. Bulletin Sx-35.

Non-Sparking Safety Tools

If your work is near inflammable gases, explosives, etc., the new 20-page catalog featuring Ampco non-sparking safety tools will prove interesting and valuable. Ampco Metal, Inc. Bulletin Bd-175.

Metallographic Equipment

The large and complete line of equipment for the laboratory made by the Fisher Scientific Co. is described in a clever leaflet just released. Bulletin Cd-182.

Houghton Products

An attractive booklet summarizing the leading products which E. F. Houghton & Co. is supplying in volume to the metal industries of the world is now available. Bulletin Cd-38.

Die Steels

An interesting 12-page booklet, well illustrated with pictures and graphs, gives uses of die steels manufactured by the Jessop Steel Co. Bulletin Ed-173.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Heat-Corrosion Resisting

A handsome new 56-page book on electrical heat and corrosion resisting alloys containing general information and useful data about such alloys has just been published by the Driver-Harris Co. Bulletin Cd-19.

Hardening Furnace

A new pamphlet which describes "Certain Curtain" furnaces made by C. I. Hayes, Inc., will be particularly interesting to those with hardening problems. Bulletin Nc-15.

Tool Steels

Matched tool steels are explained in a 60-page manual which is proving most helpful to tool steel users. Supplied by Carpenter Steel Co. Bulletin Lc-12.

Carburizer

Modern is the furnace and modern is the catalog which describes it. Hevi Duty Electric Co. has an exceptionally well-written, well-illustrated, and artistically printed booklet on the Hevi Duty carburizer which uses the Carbonol process. Bulletin La-44.

Heat Treat Chart

Heat treaters everywhere should find a heat treating wall chart complete with S.A.E. specifications a very valuable addition to their shops. Published by Chicago Flexible Shaft Co., manufacturers of Stewart industrial furnaces. Bulletin Ka-49.

Bessemer Steel

Jones & Laughlin Steel Corp. has for distribution reprints of the paper by C. C. Henning on "Manufacture and Properties of Bessemer Steel" that received the Robert W. Hunt Award of the A.I.M.E. Bulletin Ca-50.

Laboratory Furnace

The Sentry Co. describes a high temperature tube combustion furnace. It permits operating temperatures up to 2500° F., thus offering greater speed and precision for combustion analysis or other laboratory procedures. Bulletin My-114.

Pot Furnaces

Cylindrical type Pot Furnaces for Lead, Salt, and Cyanide baths are illustrated and described in a leaflet issued by the American Electric Furnace Company. These furnaces are adapted for practically any heat treating operations using a liquid medium. Bulletin Kb-2.

New Pot Furnace

Thirty per cent recuperation of fuel is one of the features of the new type pot furnace developed by A. F. Holden Co. which features unusual fuel economy and efficiency. Bulletin Ed-55.

Metal Progress, 7301 Euclid Avenue, Cleveland, O.

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Ec-229		Dd-145	Ed-261	Ed-135	Ec-226	He-90					Kb-2
		Ox-74	Ed-53		Ec-113						Ed-55
					Nc-110						